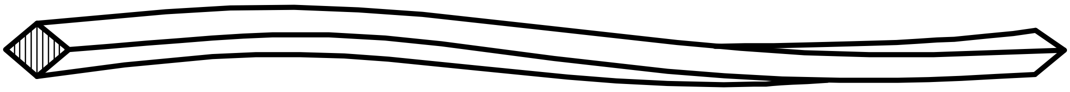
Design of beams due to Torsional Moment.

Twisting Moment



تصميم الكمرات على عزم الإلتـواء

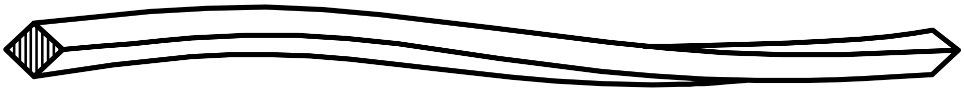
نسألكم الدعاء

IF you download the Free APP. RC Structures YASSER EL LEATHY on your smart phone or tablet, you will be able to play illustrative movies For any paragraph that has a QR code icon

اذا حملت تطبيق RC Structures YASSER EL LEATHY على تليفونك المحمول او اللوح السطحى ستستطيع أن تشغل أفلام شرح للمقاطع التى تحتوى على رمز

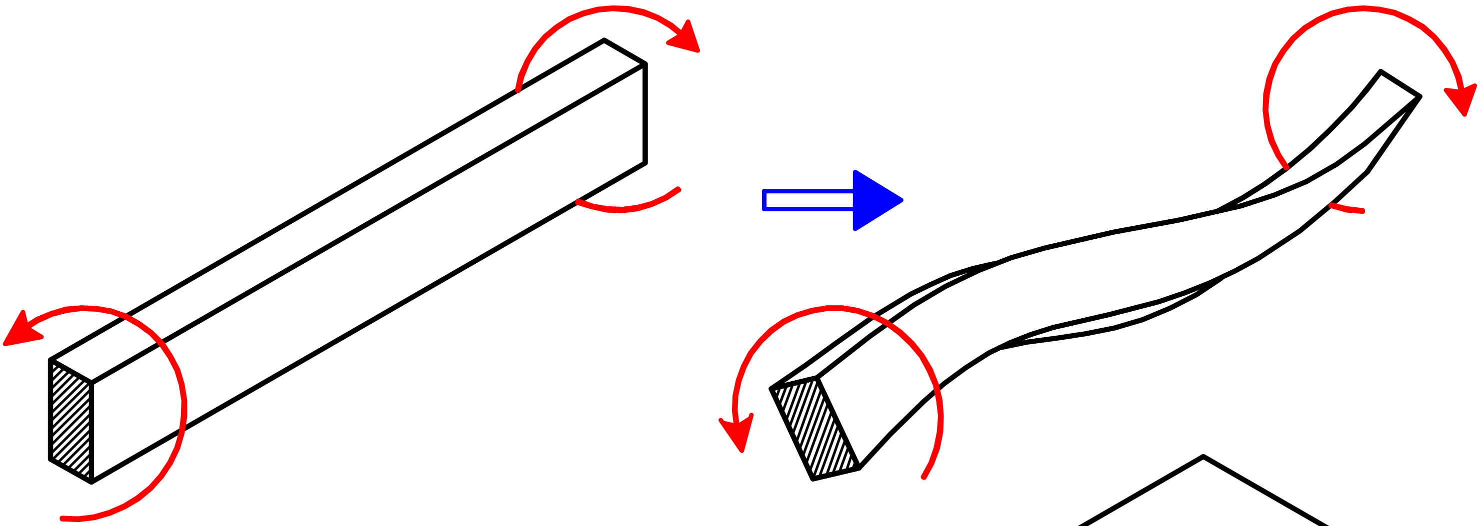
Design Beams due to Torsion Table of Contents.

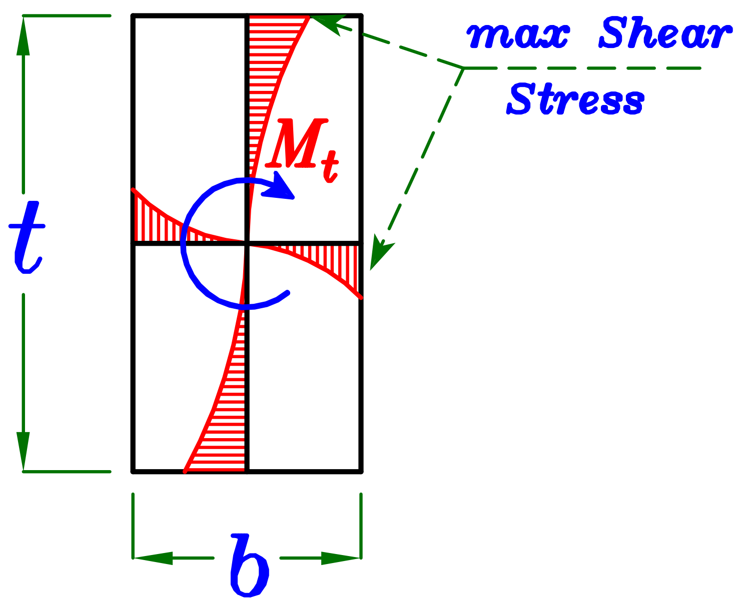
Torsion Moment.

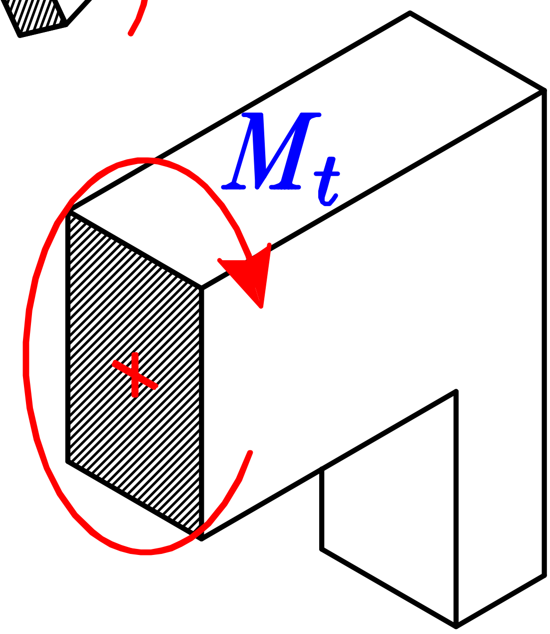


عزم الإلتـواء

عزم الالتواء هو عزم ينتج عندما تدور الكمره حول محورها .







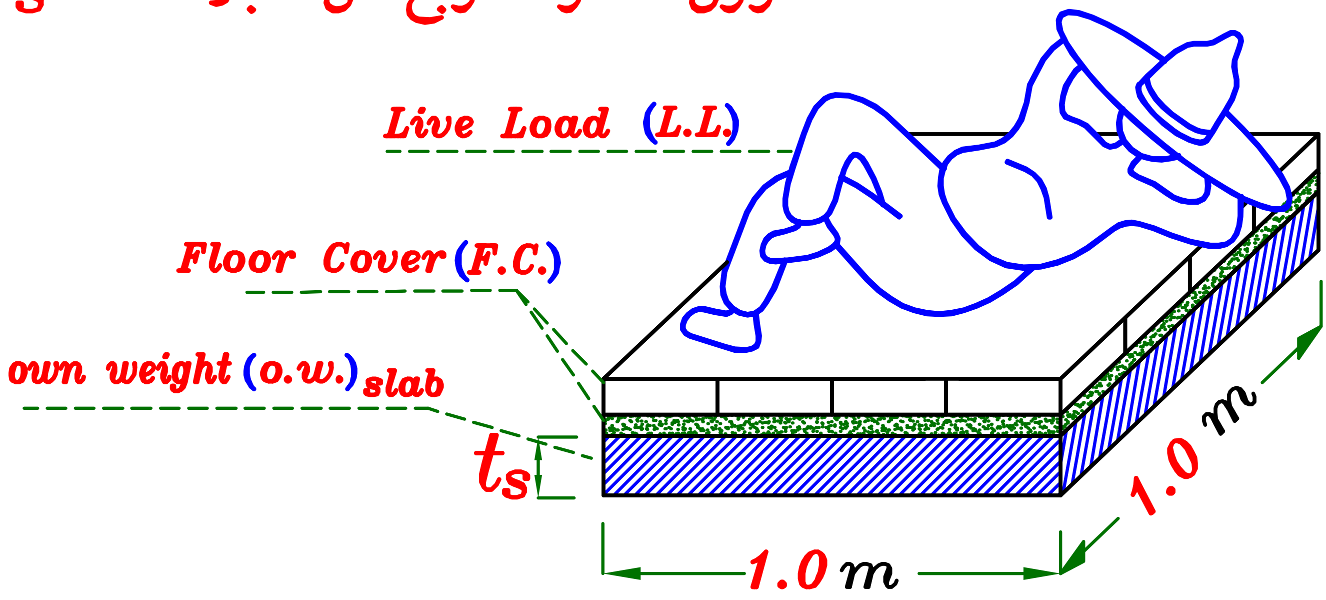
تنتج إجهادات القص *Shear Stresses* على الكمرات عن طريق

1. *Shear Force* (Q) ---------------- قوى القص
2. *Torsional Moment* (M_t) -------عزم الإلتـواء

لـذا سيتم تصميم الكانات لتتحمل كلاً من *Shear Force* & *Torsional Moment*

Strip in the Slab. شريحه فى البلاطه .

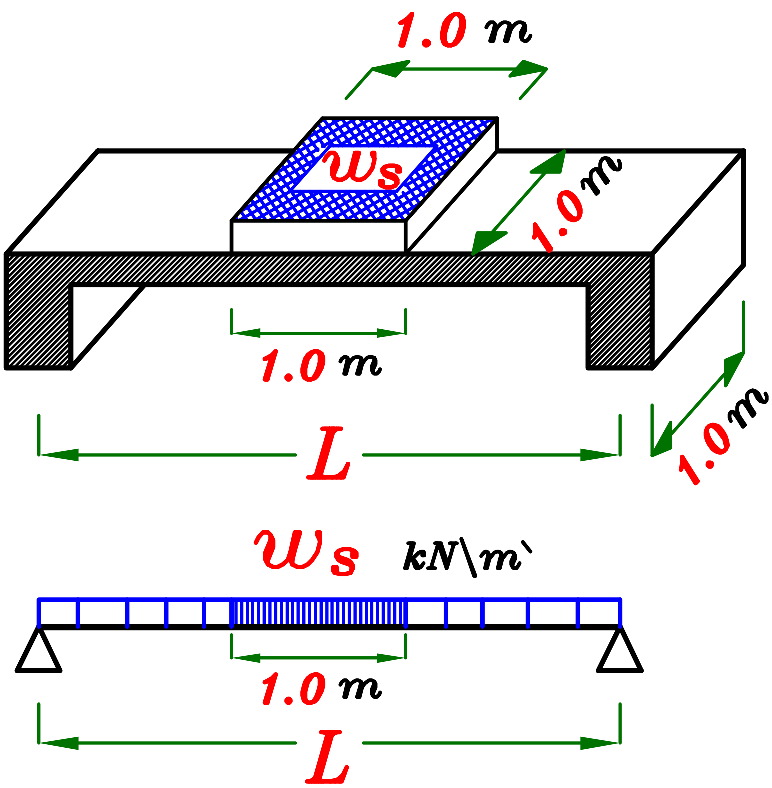
w_s = وزن المتر المربع من البلاطه

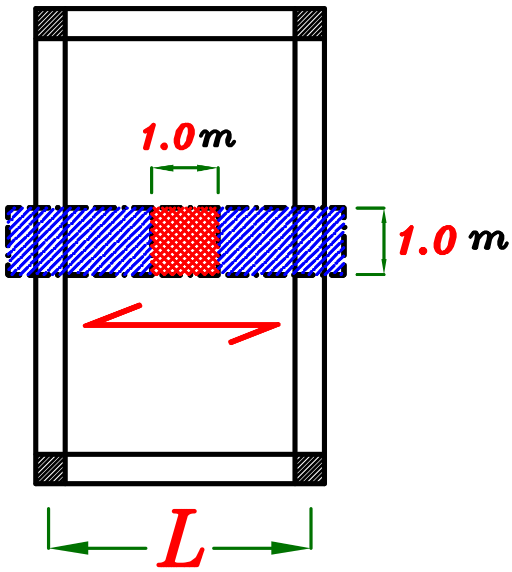


$$\boxed{(w_s)_{U.L.} = 1.4\,(t_s\,\gamma_c + F.C.) + 1.6\,(L.L.)} \quad kN\backslash m^2$$

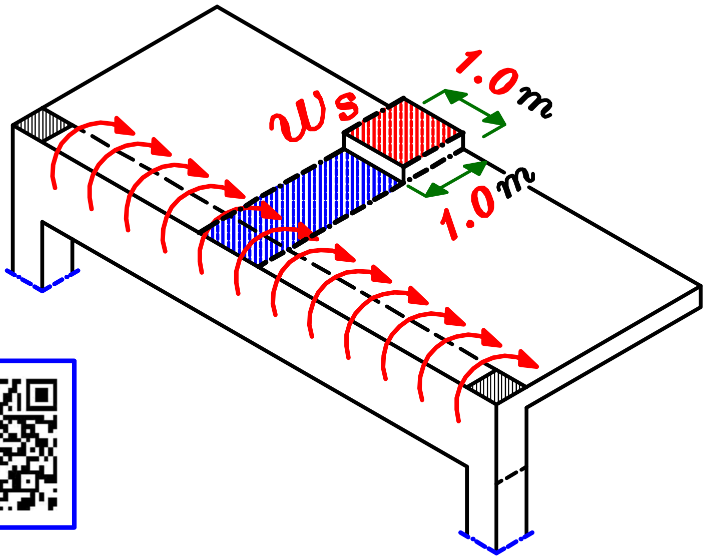
عند أخذ شريحه فى البلاطه فى اتجاه ال *Load* عرضها ١٫٠ م

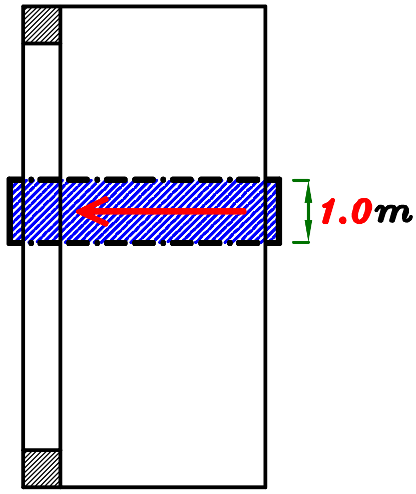
نضع عليها حمل منتظم *uniform Load* قيمته w_s





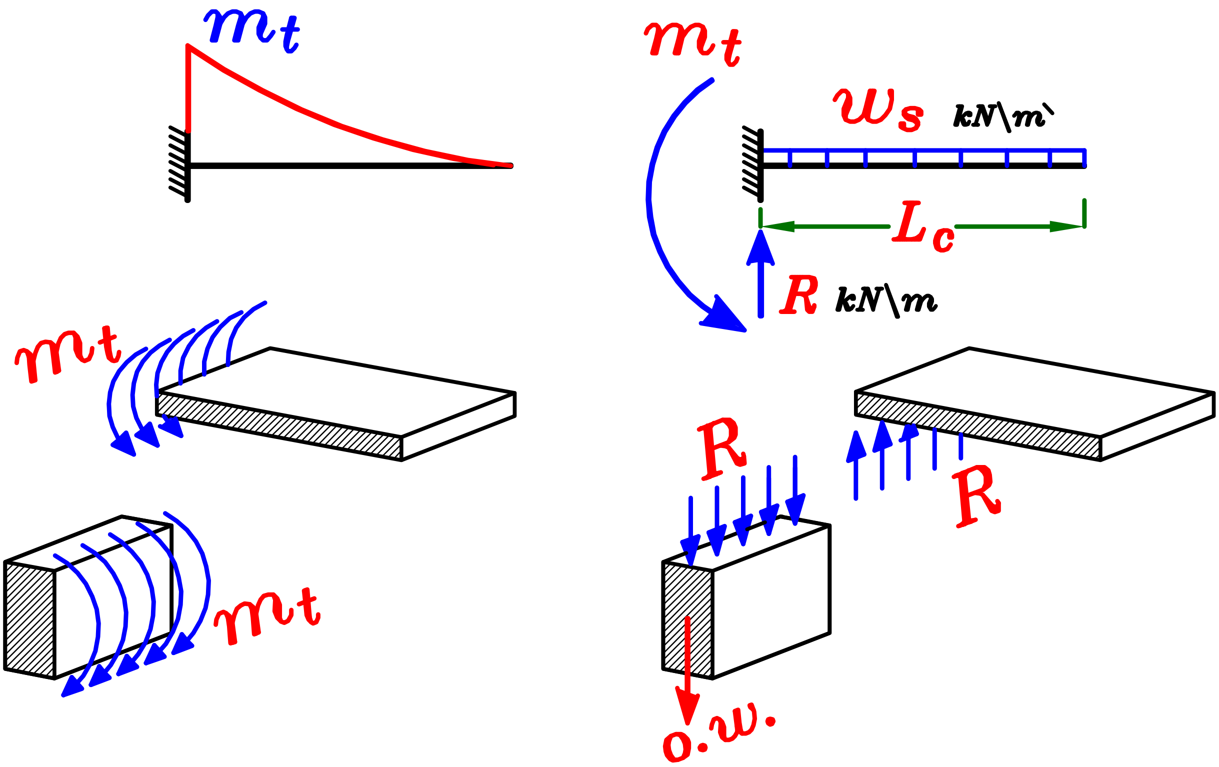
١- تكون الكمره عليها *Torsion* منتظم عندما تكون شريحه البلاطه محموله على كمره واحده .
أما اذا كانت الشريحه محموله على أكثر من كمره فلن يوجد أى *Torsion* على الكمرات .



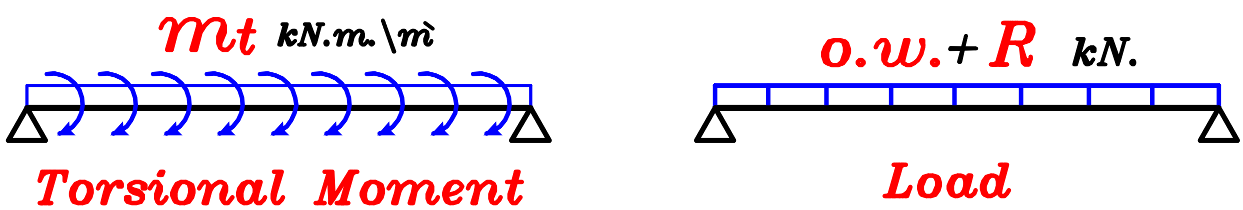


نأخذ شريحه فى البلاطه فى اتجاه الـ *Load* عرضها ١,٠ م

Take a strip in the slab at the load direction with width 1.0m



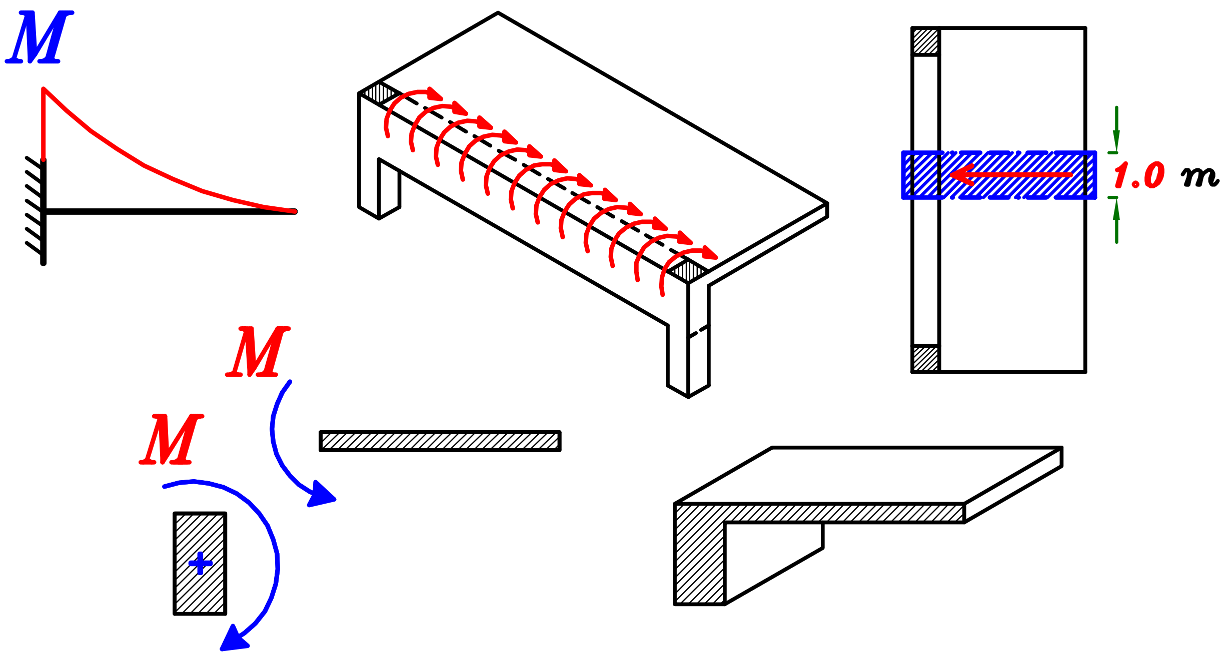
Beam.



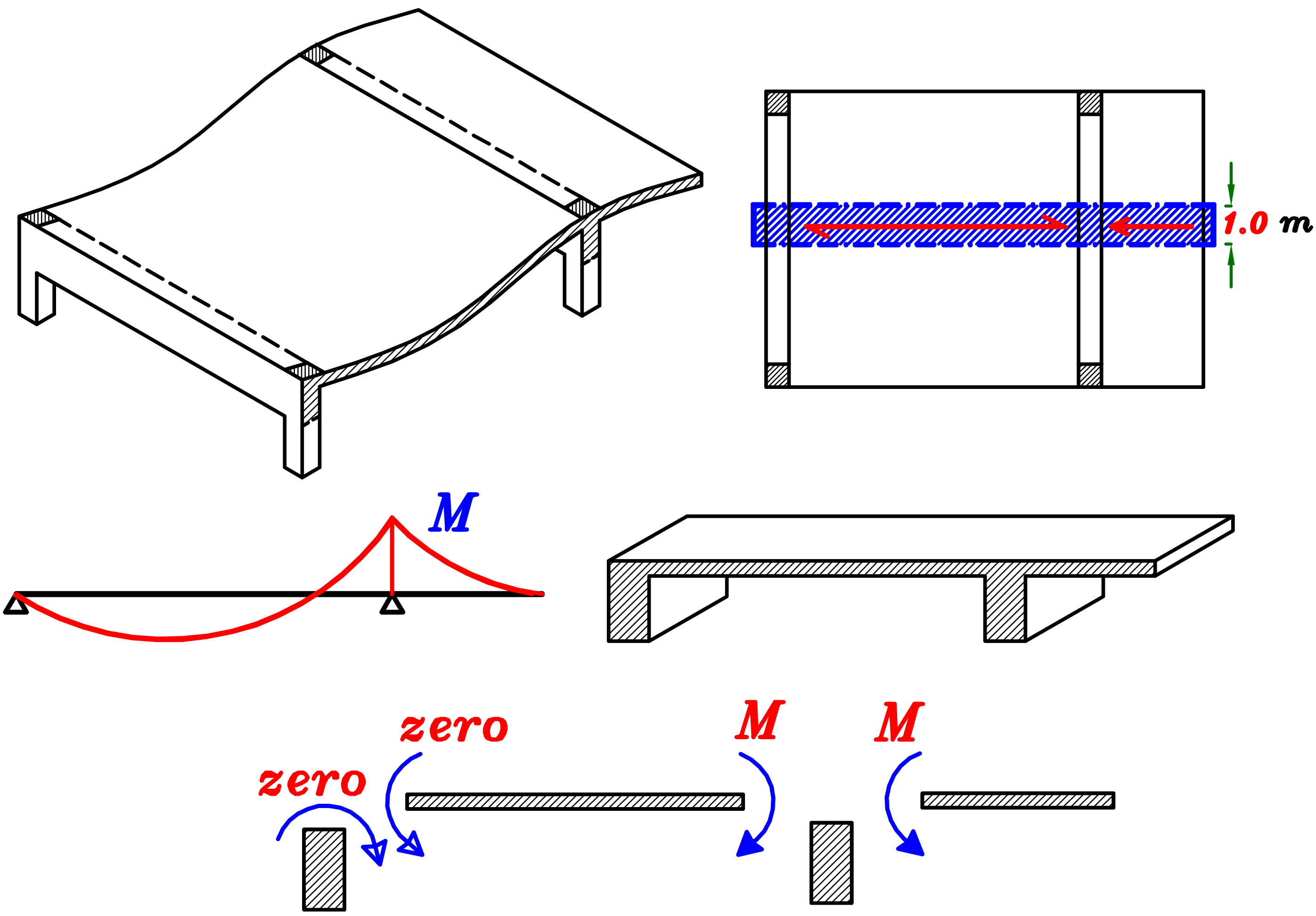
ملحوظه .

ينتقل عزم الالتواء من البلاطه الى الكمره

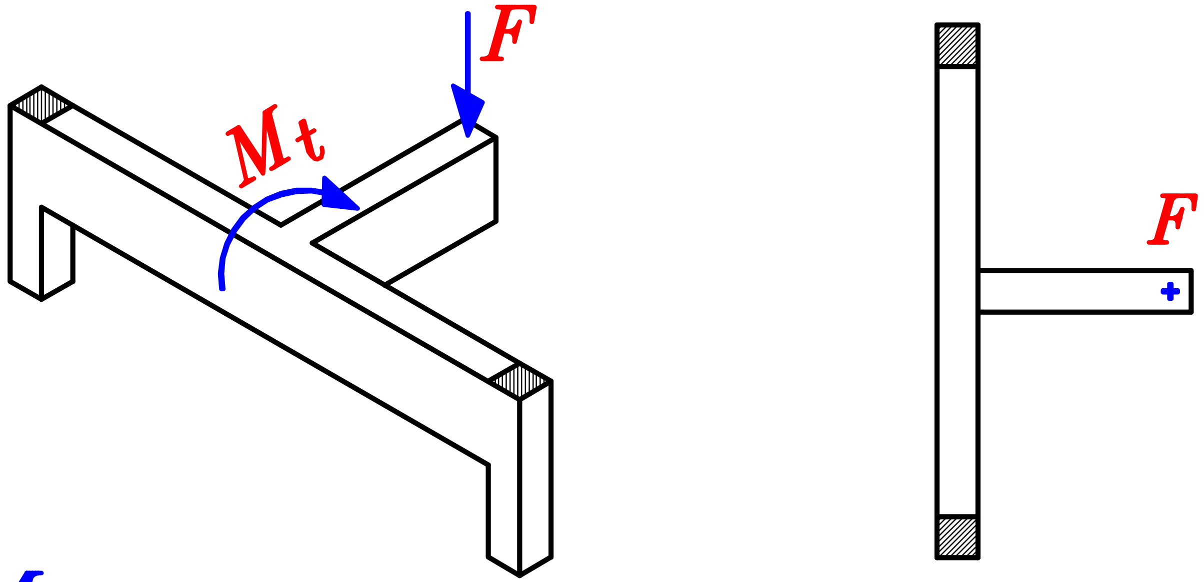
اذا كانت شريحه البلاطه محموله على كمره واحده فقط فيعمل **Torsion** على الكمره .

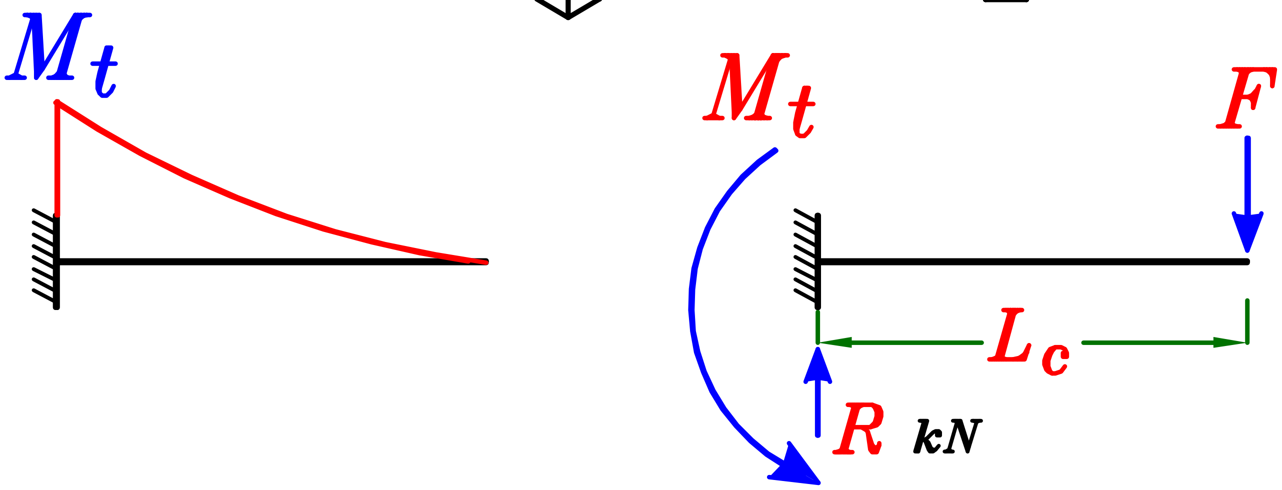


اذا كانت شريحه البلاطه محموله على اكثر من كمره لن يكون هناك **Torsion**
لان العزم سينتقل من البلاطه للبلاطه المجاوره مباشره .

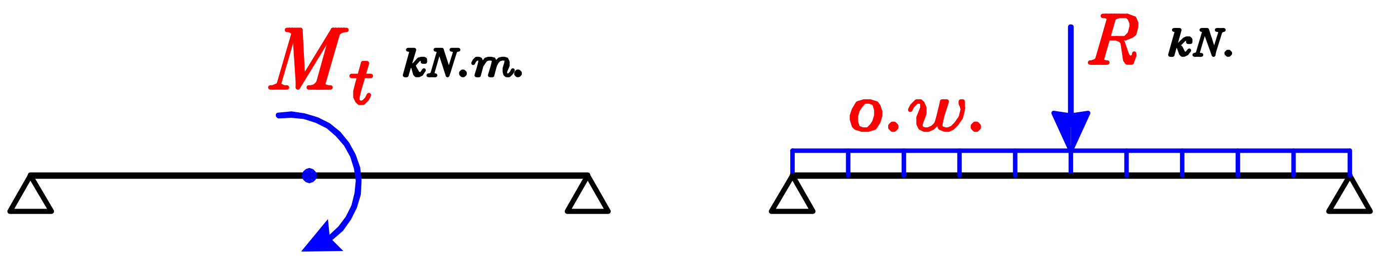


٢- تكون الكمره عليها **Torsion** مركز عندما تكون كمره محموله على كمره واحده فقط.





Beam.

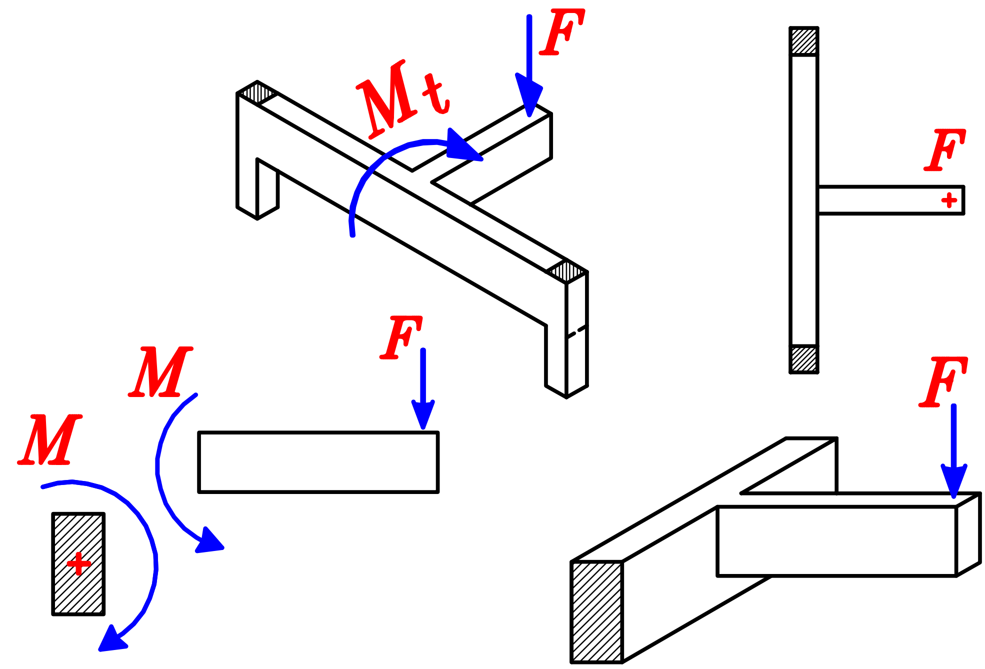


Torsional Moment **Load**

ملحوظه .

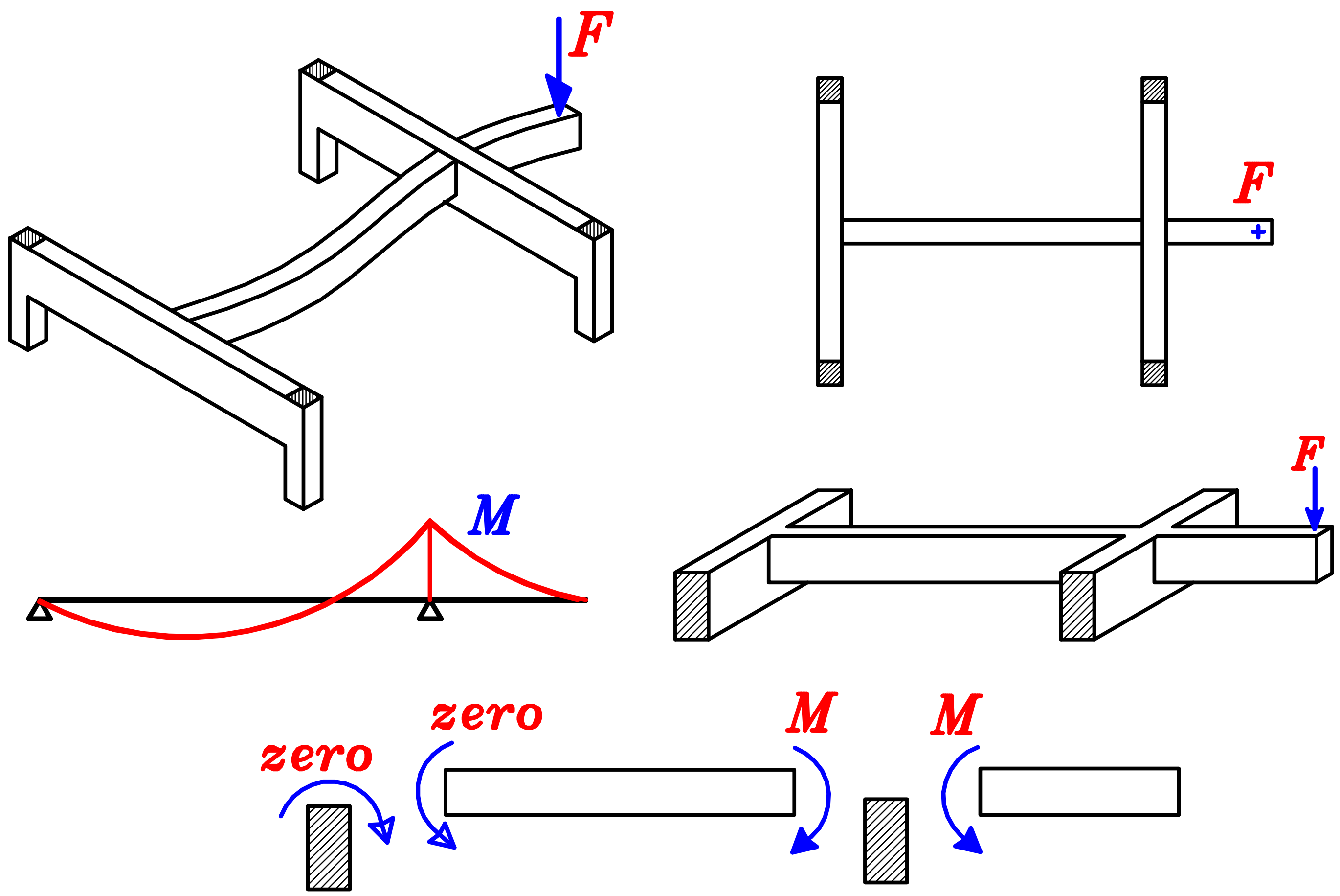
ينتقل عزم الالتواء من الكمره الـ Cantilever الى الكمره التى تحملها .

لان الكمره الـ Cantilever محموله على كمره واحده فقط.

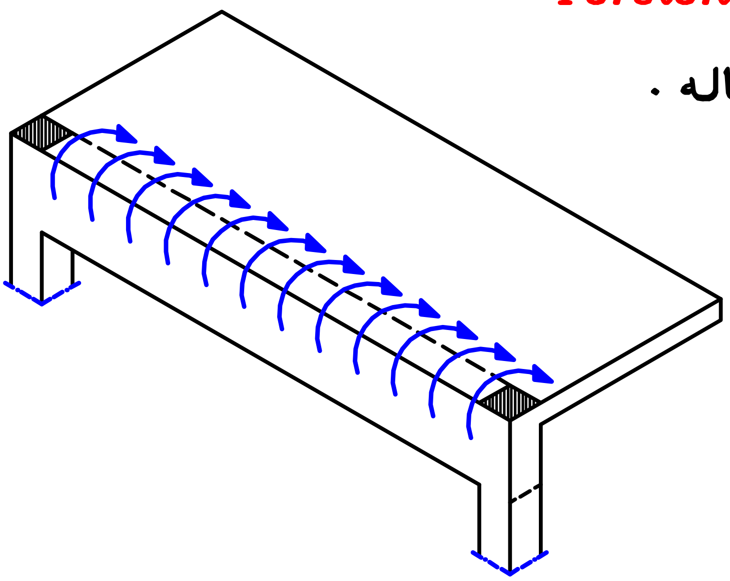


اذا كانت الكمره محموله على اكثر من كمره سينتقل العزم من الـ cantilever

الى الباكيه التاليه دون ان ينقل torsion على الكمره الحامله .



Equilibrium Torsion (Primary Torsion).



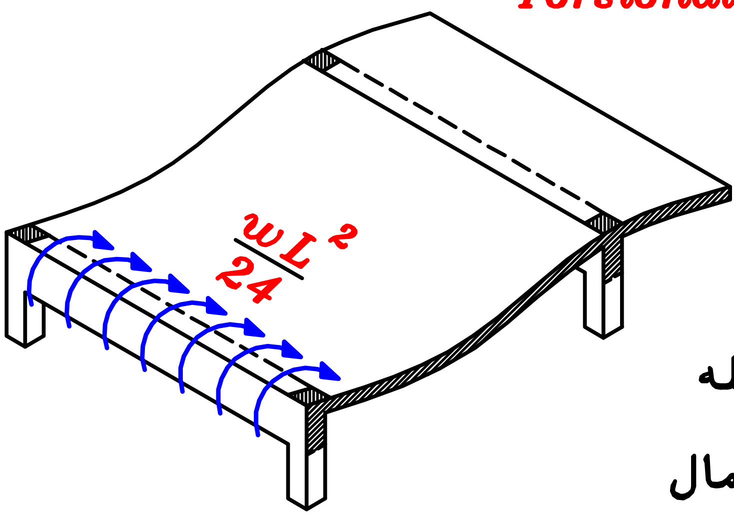
و هى الحاله التى يكون ال Torsional Moment أساسى لعمل اتزان للكمره و لا يمكن اهماله .

و فى هذه الحاله لا نستطيع أن نقلل من قيمه ال Torsional Moment عن طريق التسليح او اعاده توزيع الاحمال

و فى هذا النوع يجب ان يوضع تسليح ليقاوم ال Torsional Moment و لا يمكن اهماله .

Compatibility Torsion (Secondary Torsion).

و هى الحاله التى يكون ال Torsional Moment غير أساسى لعمل اتزان للكمره .



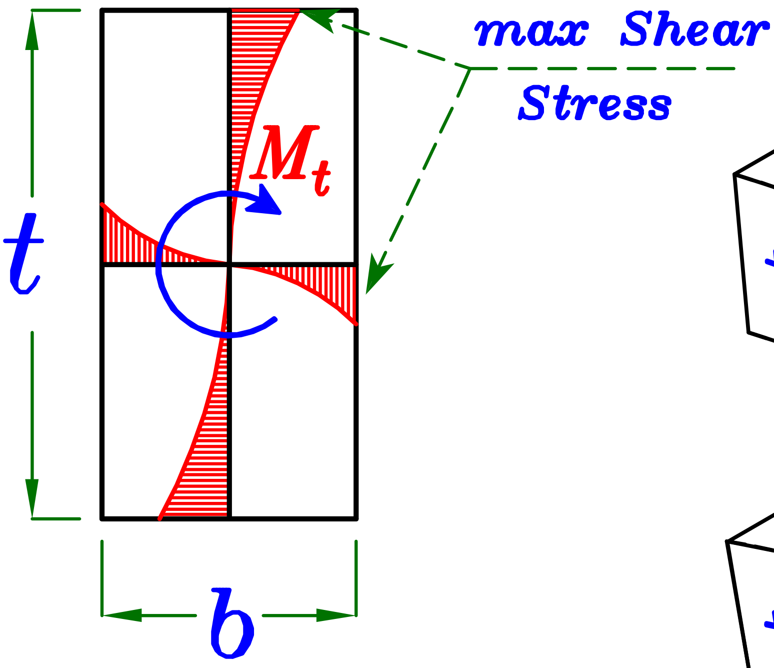
و فى هذه الحاله نستطيع أن نقلل من قيمه ال Torsional Moment أو نهمله عن طريق التسليح او اعاده توزيع الاحمال

و فى هذا النوع ممكن اهمال وضع تسليح ليقاوم ال Torsional Moment حيث عدم وضع تسليح لل Torsional Moment سيؤدى لشروخ فى الخرسانه و بالتالى اعاده توزيع العزوم و الغاء ال Torsional Moment .

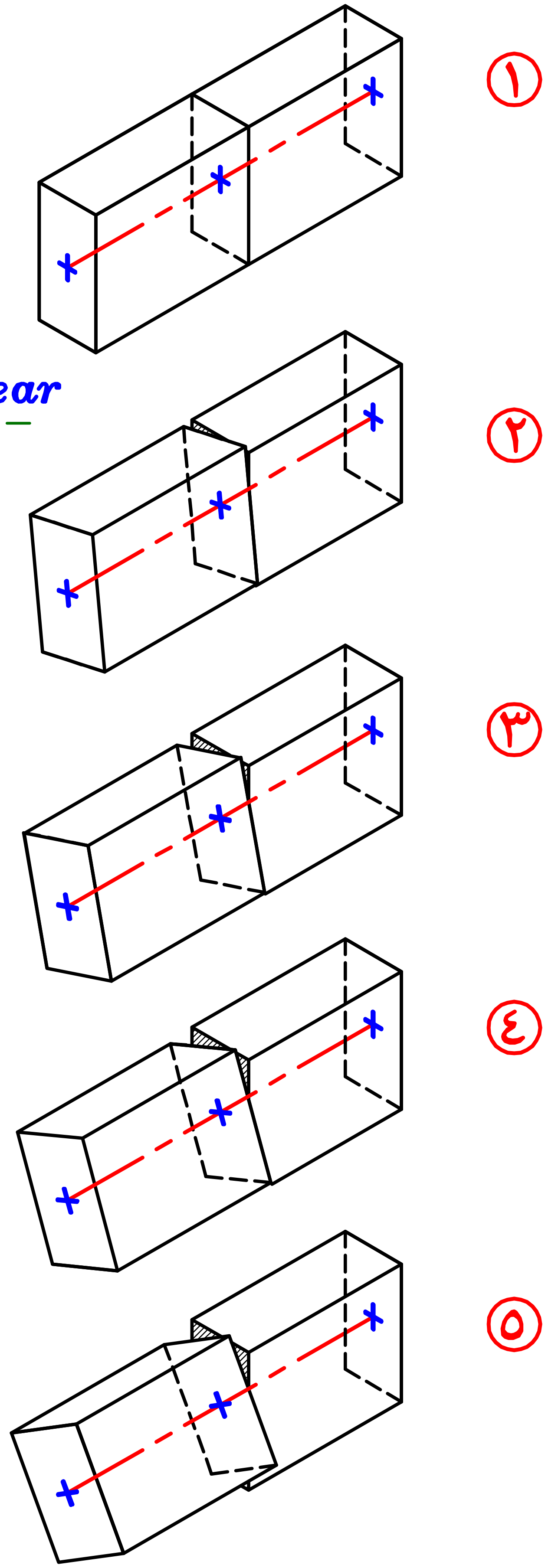
فى هذا الملف سيتم دراسه و تسليح ال Equilibrium Torsion فقط

Shear Stress due to Torsional Moment.

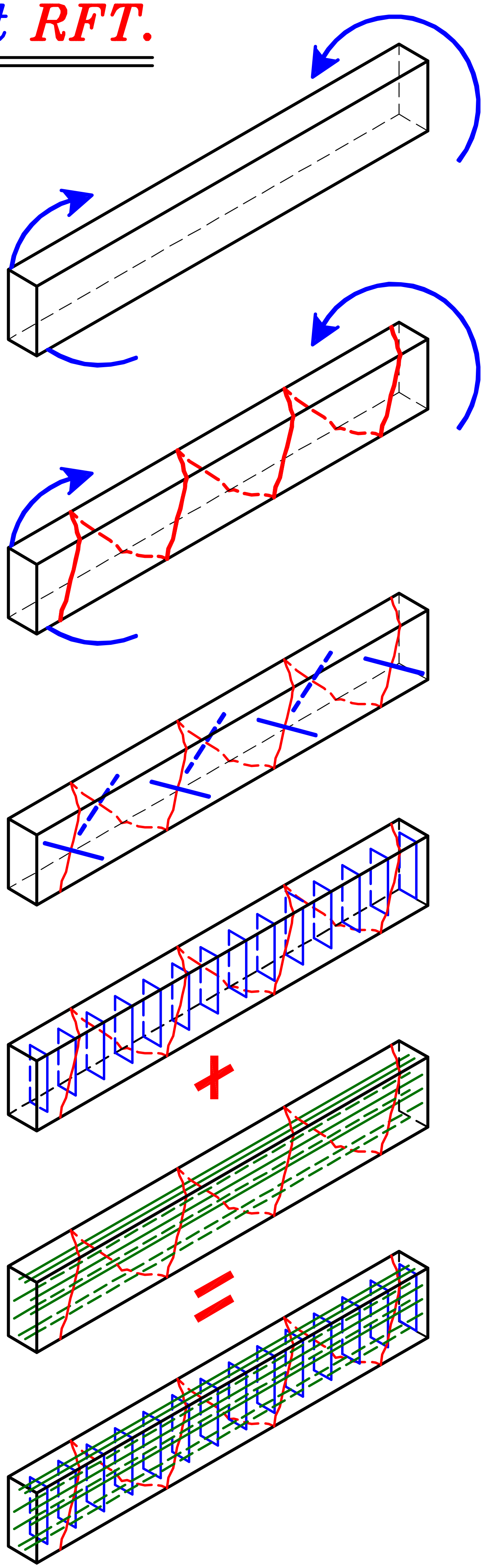
يتسبب الـ Torsional Moment فى وجود اجهادات قص ناتجه عن دوران الكمره حول محورها .
و ذلك بسبب الاحتكاك الناتج بين سطحين متلاصقين احداهما يدور بزاويه أكثر من الاخر .



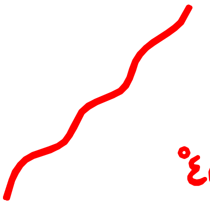
Shear Stress Distribution



Torsional Moment RFT.



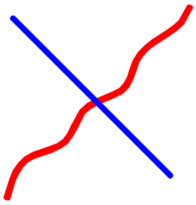
عند حدوث **Torsion** على الكمره



يكون شكل الشروخ

زاويه ميل الشرخ ٤٥°

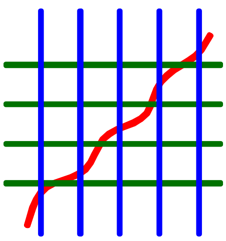
و يكون على المحيط الخارجى للكمره



افضل تسليح لمقاومه الشرخ

هو الحديد العمودى على الشرخ

و لكن تنفيذه بهذا الشكل غير عملى



لذا عمليا يوضع تسليح افقى و راسى

لمقاومه الشرخ و هى كانات راسيه

و اسياخ افقيه بطول الكمره

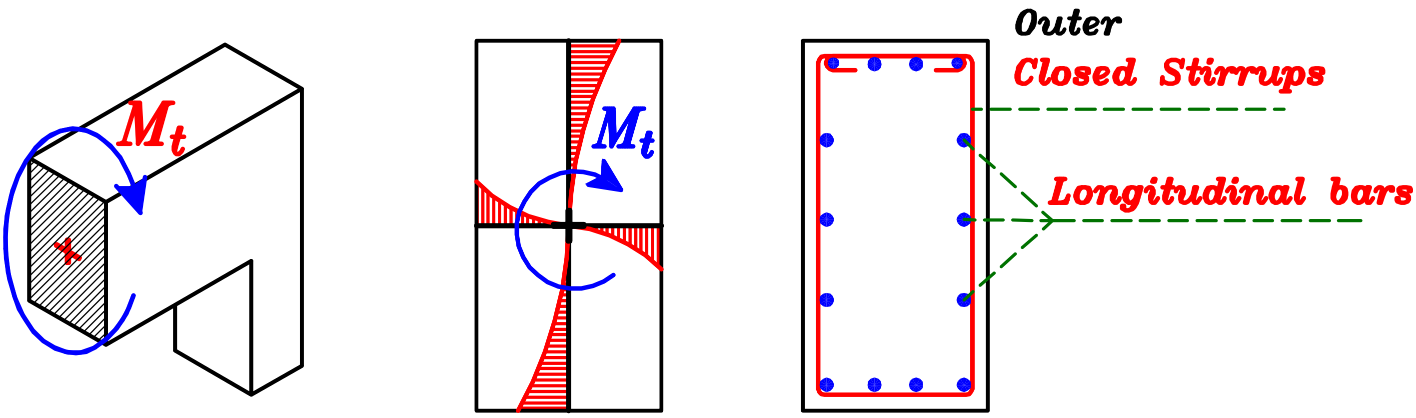
Shear + Torsion RFT.

لمقاومه ال *Torsional moment* منفردا

نحتاج لكانات خارجيه مغلقه *Closed Stirrups*

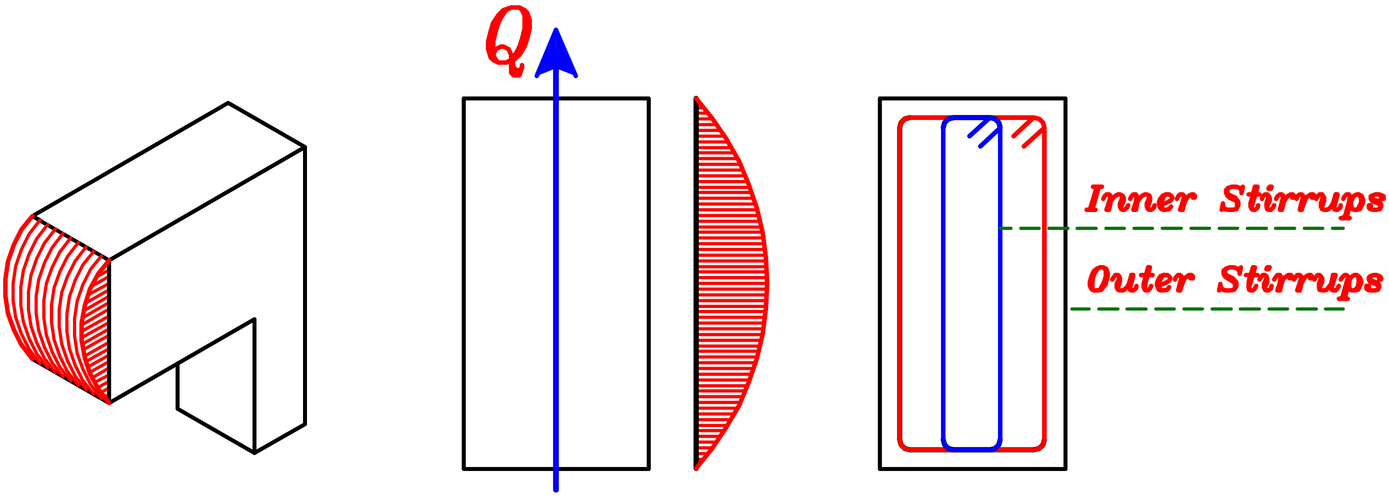
و نحتاج لاسياخ طوليه موضوعه على المحيط الخارجى للكمره *Longitudinal bars*

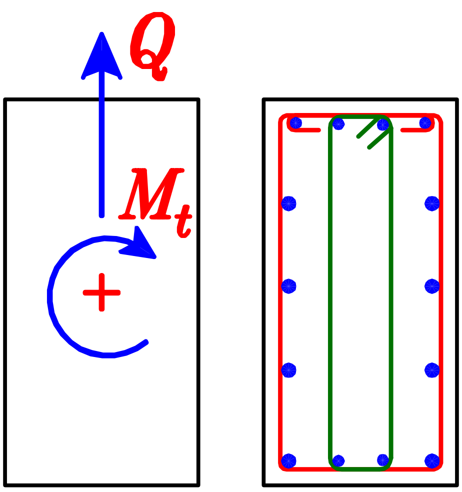
و لن نحتاج لكانات داخليه لانها لن تقاوم *Torsion* لانها ليست عند اكبر *Stress*



لمقاومه ال *Shear Force* منفردا

نحتاج لكانات خارجيه *Outer Stirrups* و ممكن وضع كانات داخليه *Inner Stirrups*





اذا لمقاومه ال *Shear Force* + *Torsional moment*

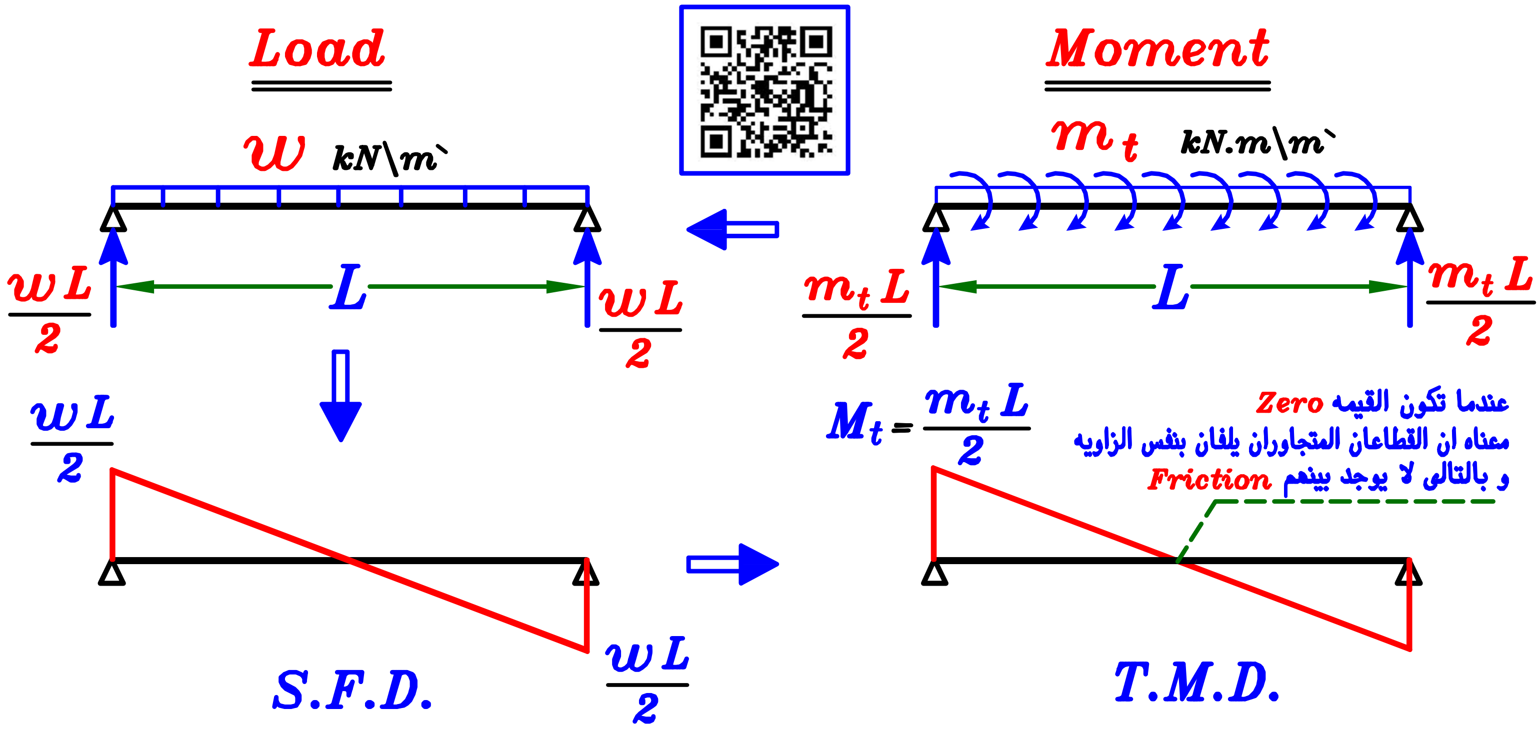
- نضع كانات خارجيه مغلقه *Outer Closed Stirrups* لمقاومه ال *Shear* و ال *Torsion* معاً.
- ممكن وضع كانات داخليه *Inner Stirrups* لمقاومه ال *Shear* فقط.
- اسياخ طوليه *Longitudinal bars* لمقاومه ال *Torsion* فقط.

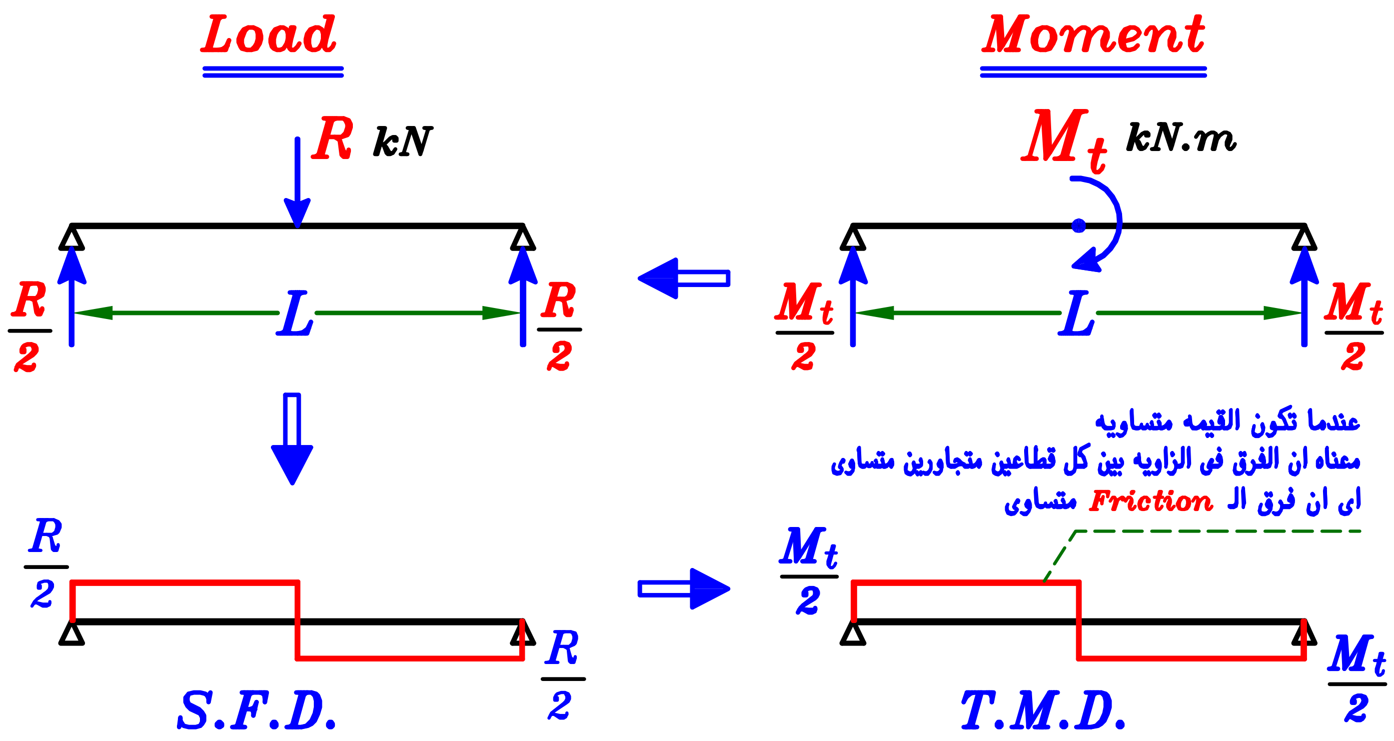
How to Draw Torsional Moment Diagram (T.M.D.)

لرسم ال (T.M.D.) Torsional Moment Diagram يرسم بنفس طريقة رسم ال S.F.D.

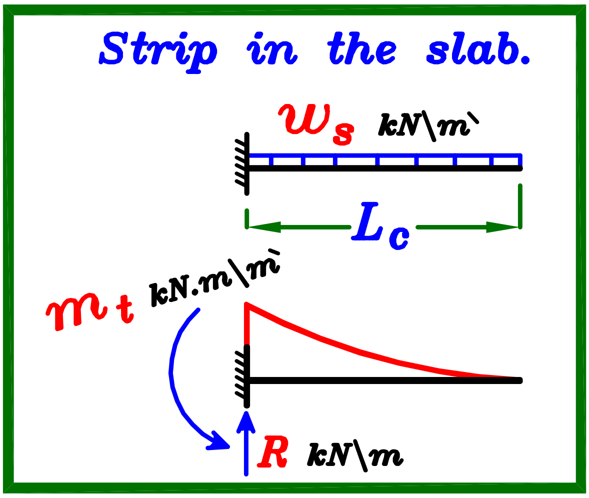
لذا عند رسم ال T.M.D. نفرض أن ال Moment عباره عن Load و نرسم

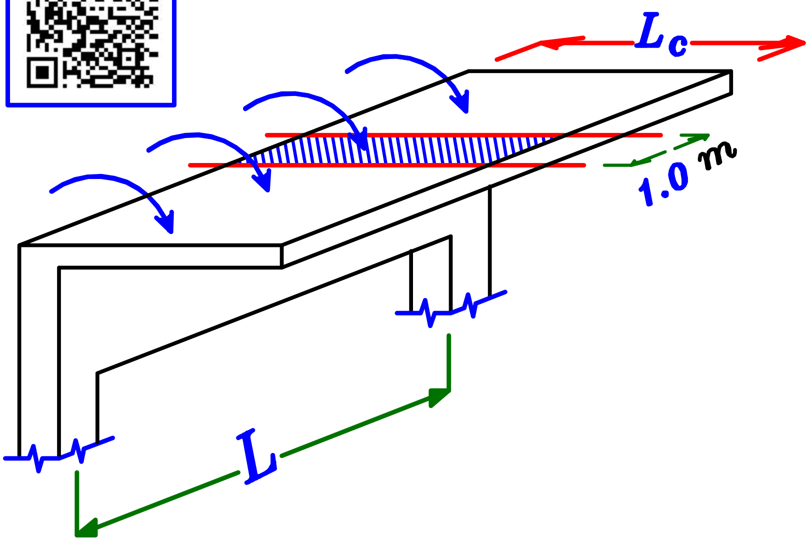
ال S.F.D. لهذا ال Load فيكون هو نفس شكل ال T.M.D. لل Moment



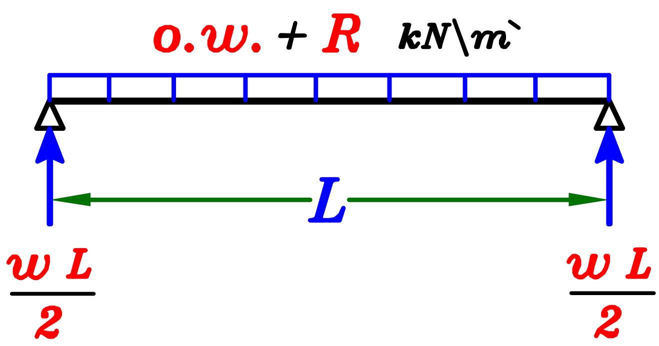


Example.

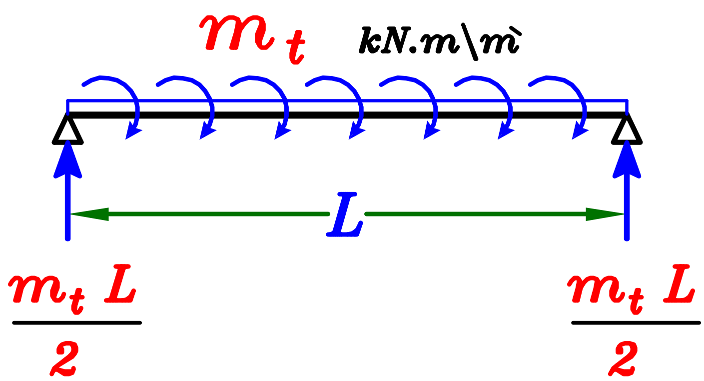


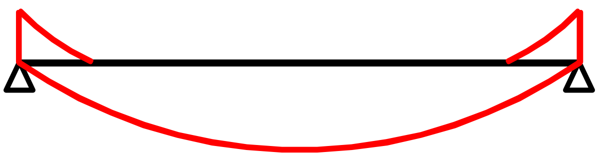


Load

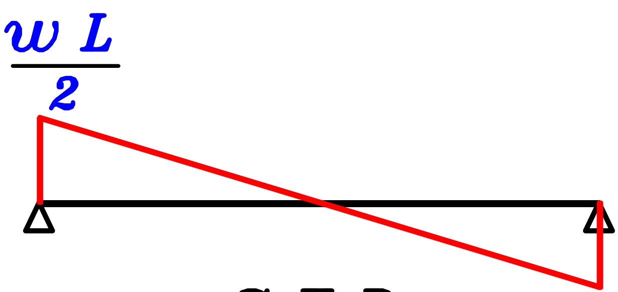


Moment

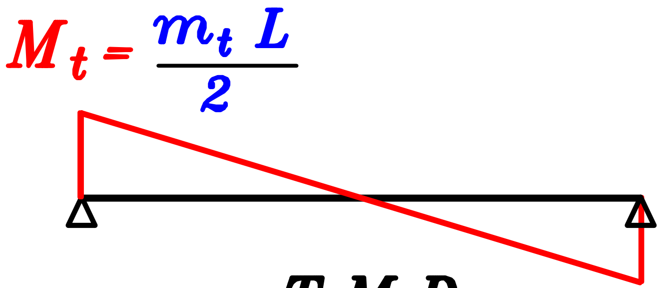




B.M.D.

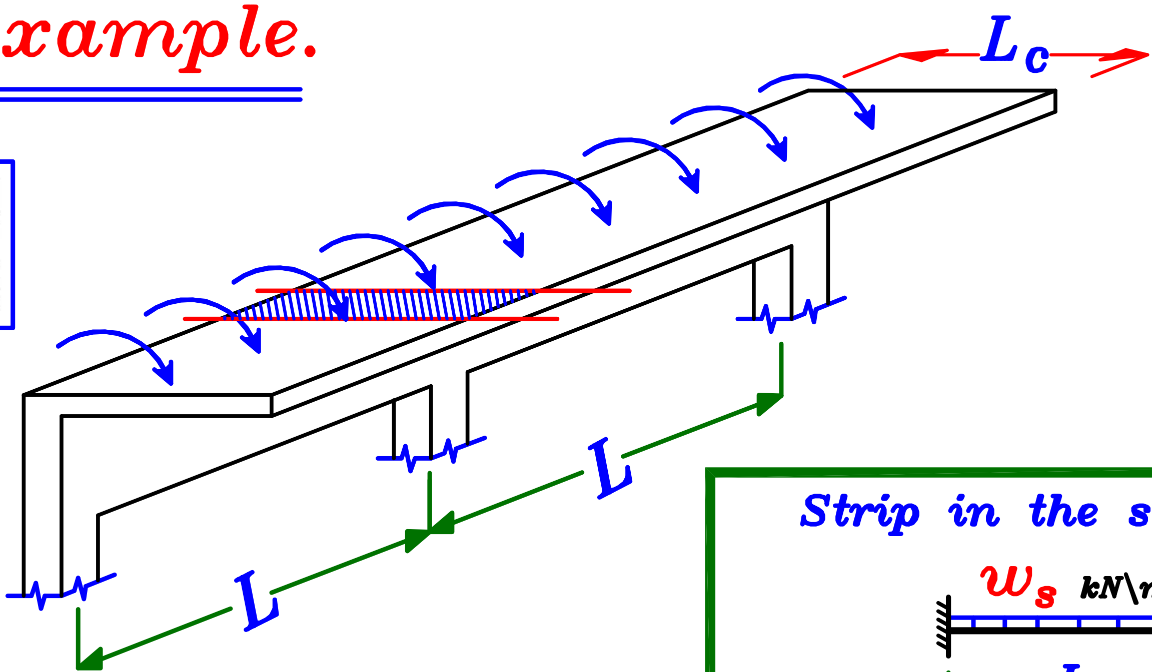


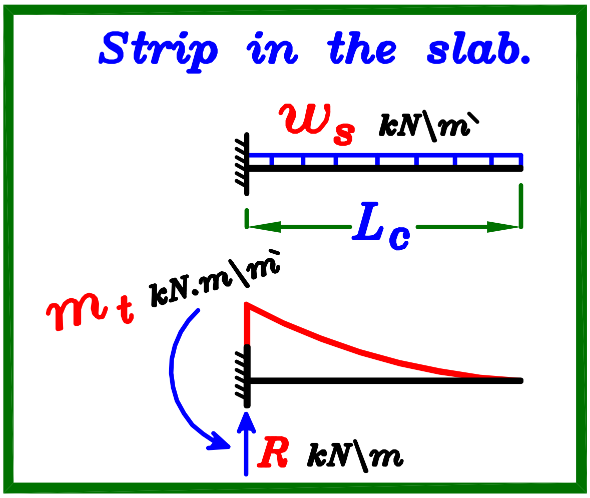
S.F.D.



T.M.D.

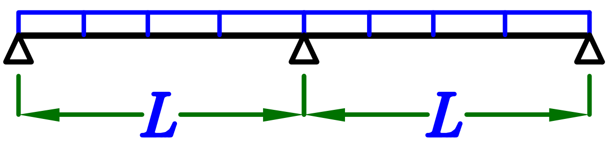
Example.





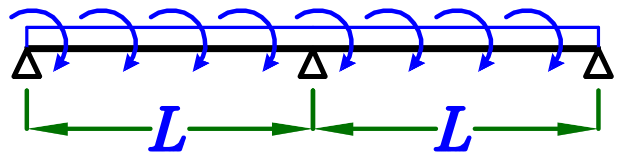
Load

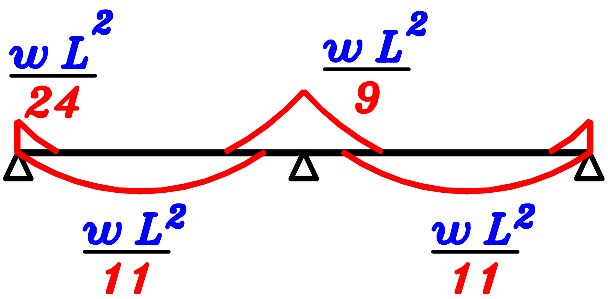
$w = o.w. + R$ kN\m`



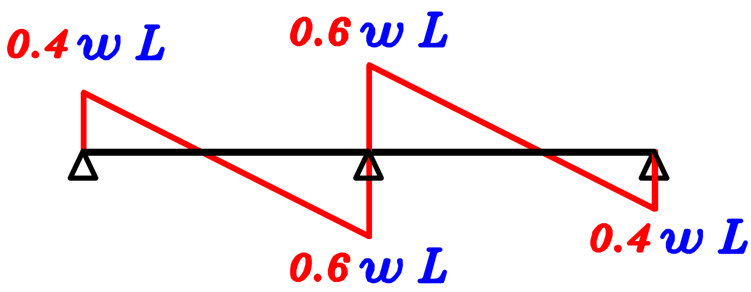
Moment

m_t kN.m\m`

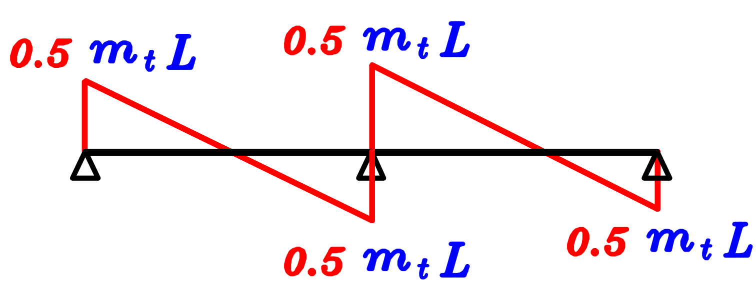




B.M.D.

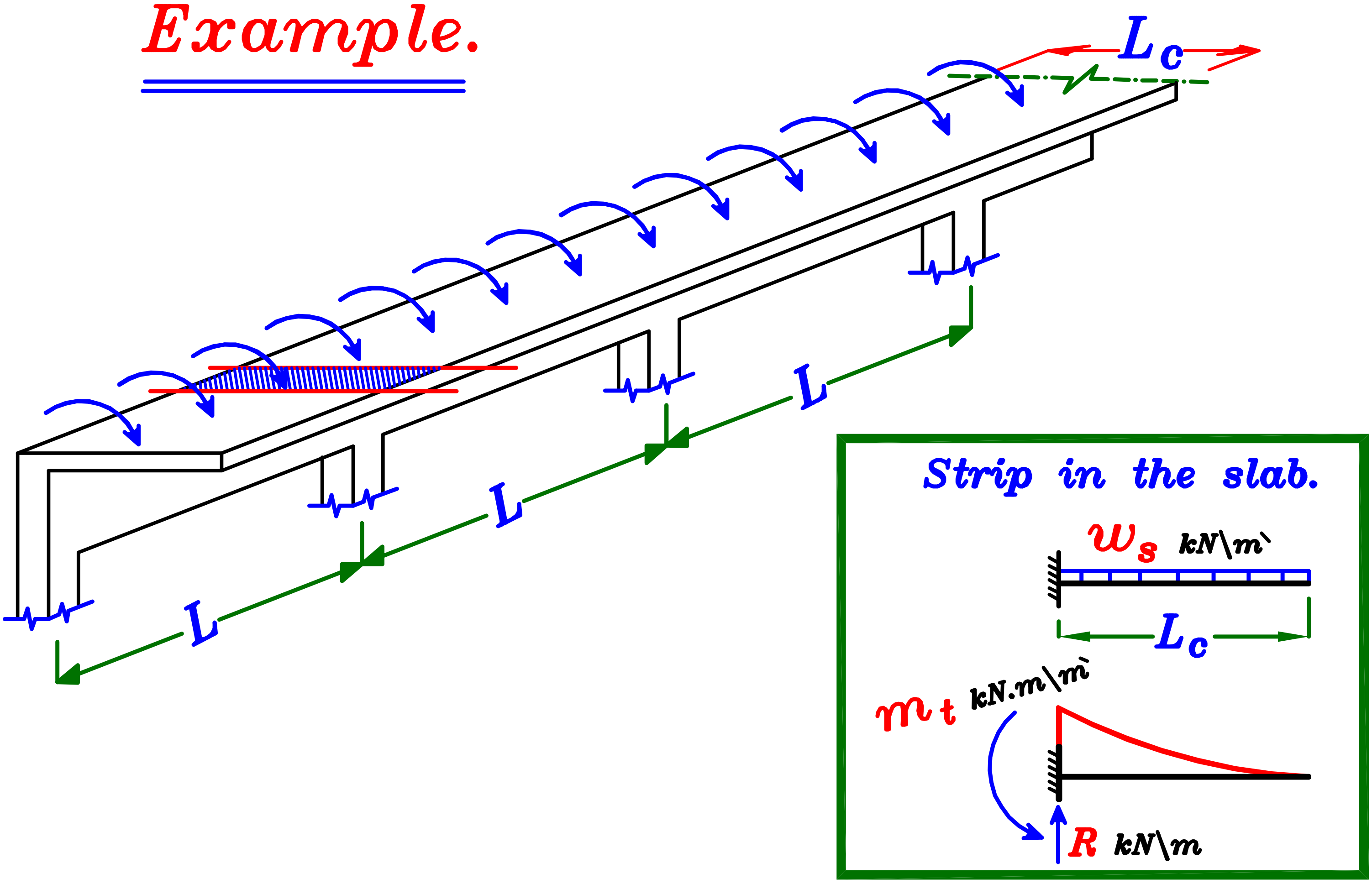


S.F.D.



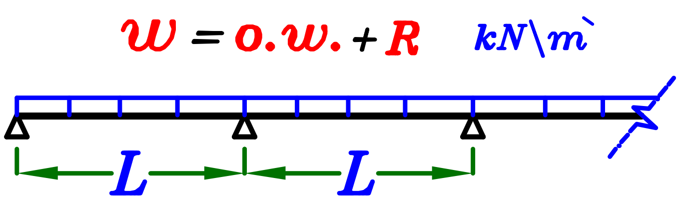
T.M.D.

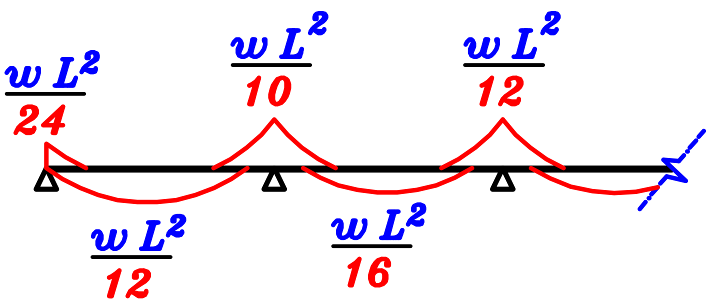
Example.



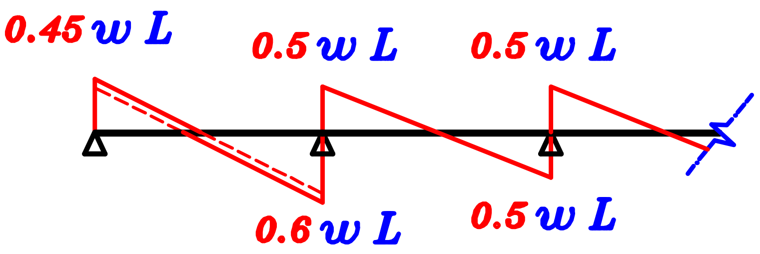
Load

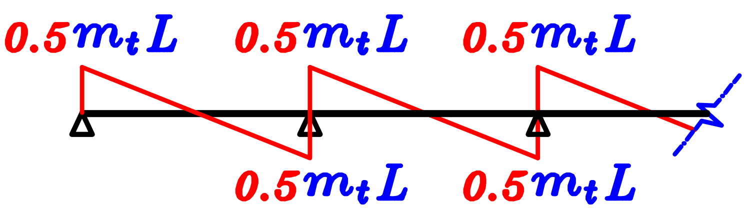
Moment





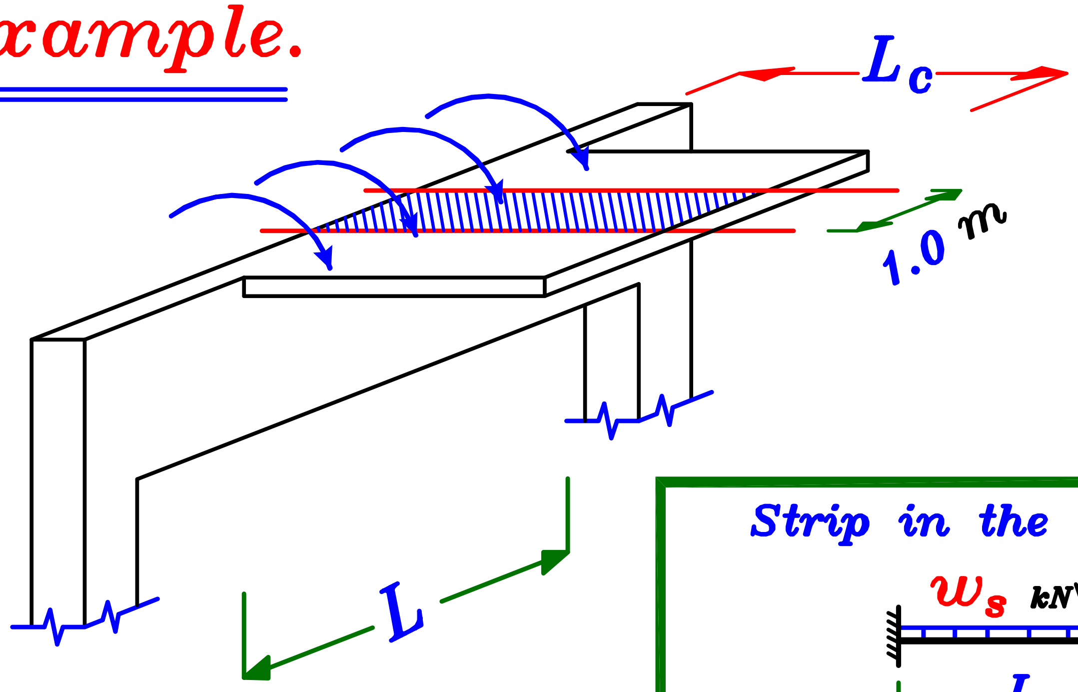
B.M.D.

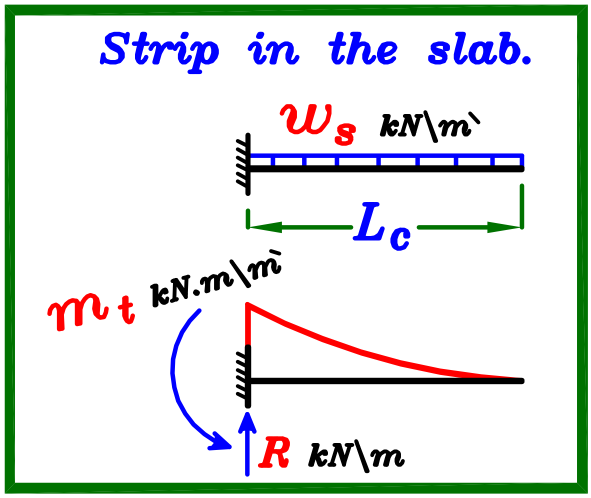




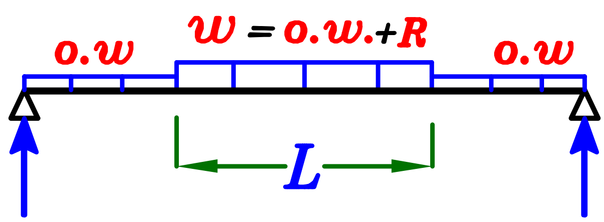
S.F.D. T.M.D.

Example.

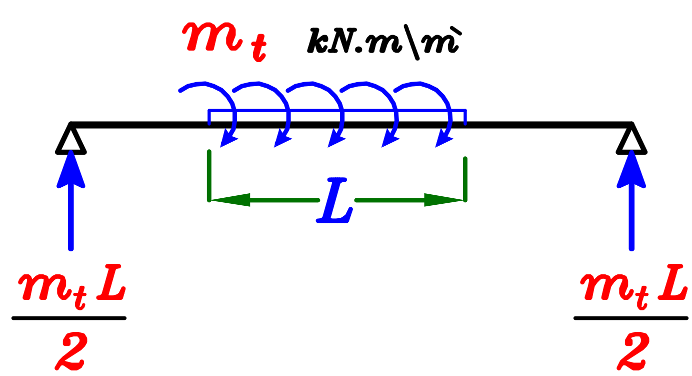


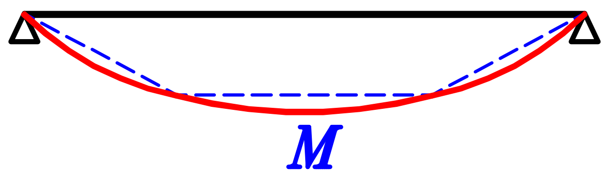


Load

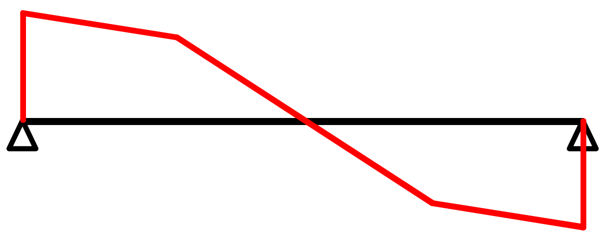


Moment



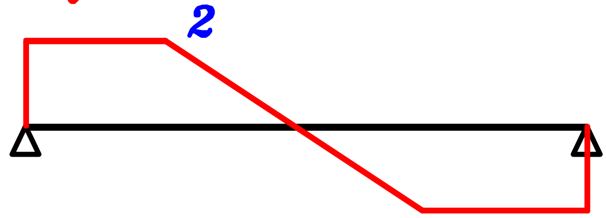


B.M.D.



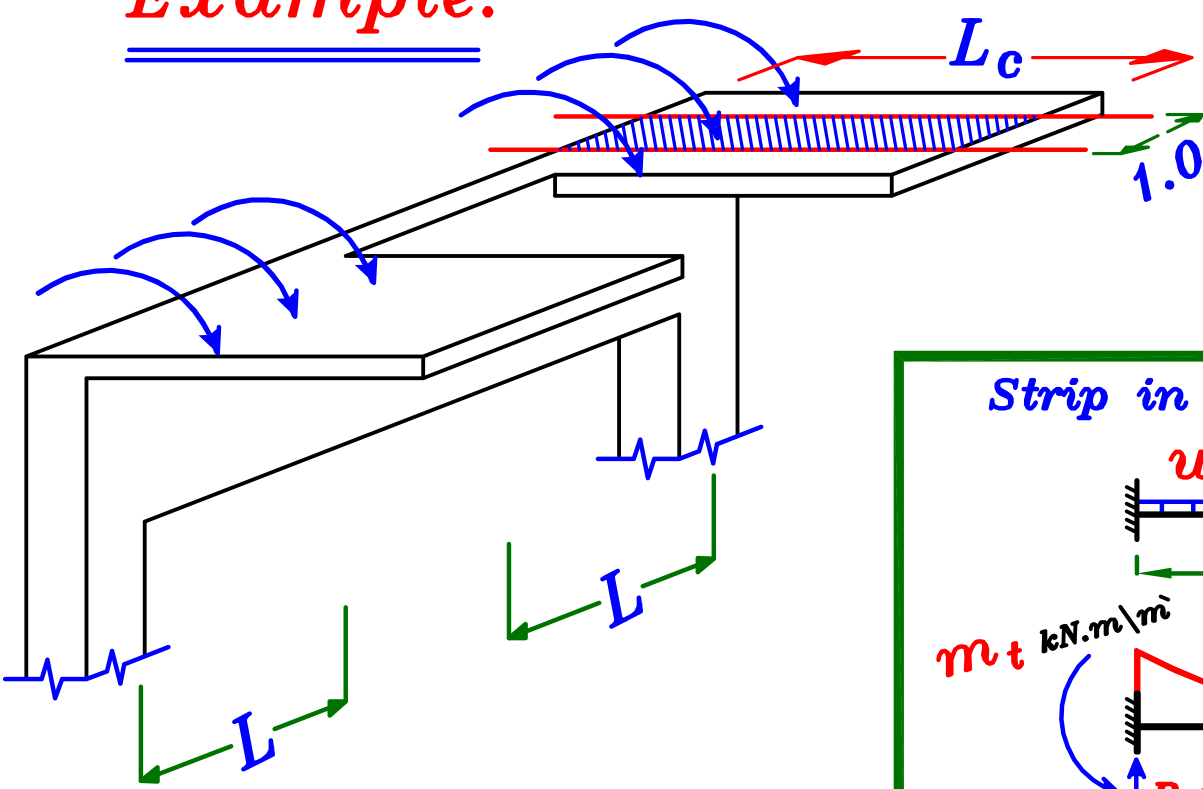
S.F.D.

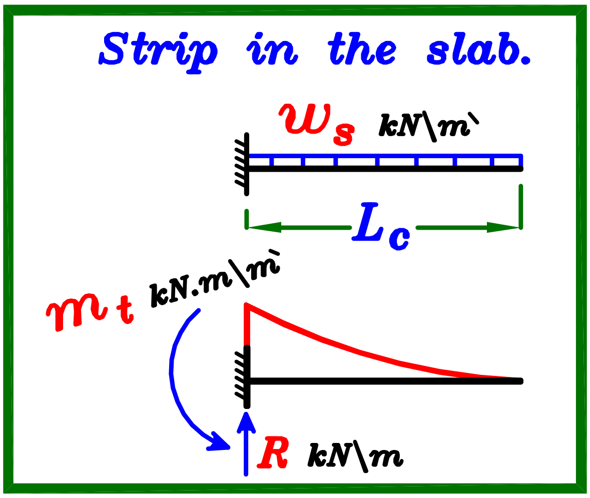
$M_t = \frac{m_t L}{2}$



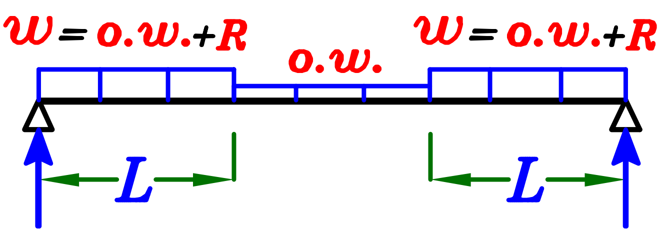
T.M.D.

Example.

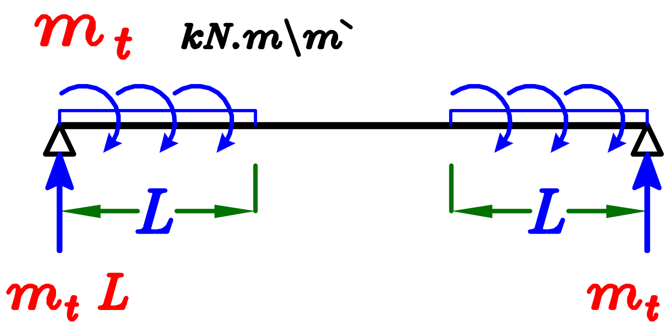


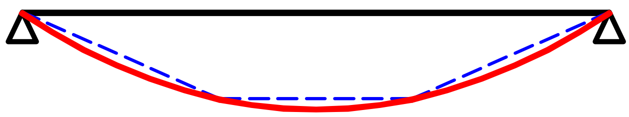


Load



Moment



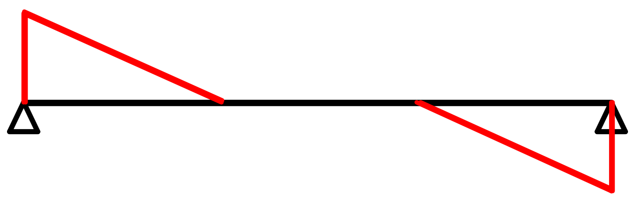


B.M.D.

M

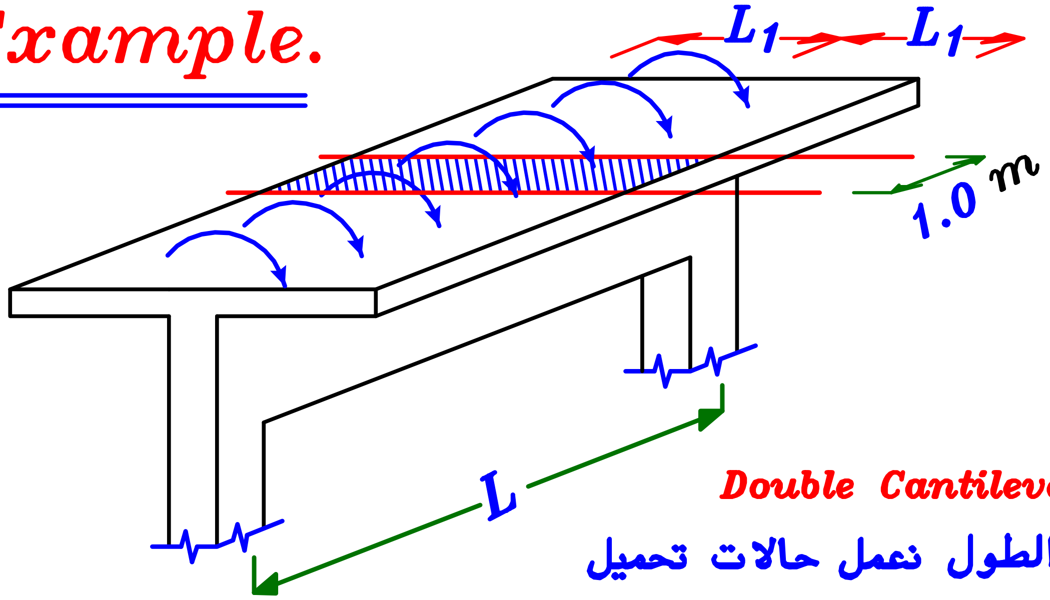
$$M_t = m_t L$$

S.F.D.

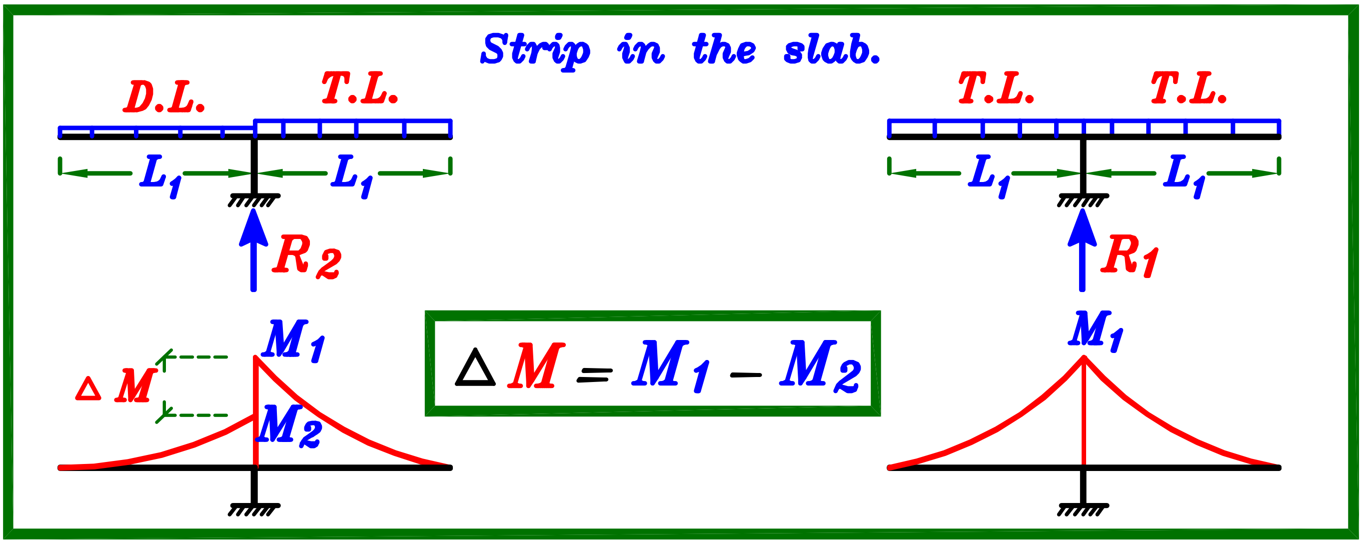


T.M.D.

Example.



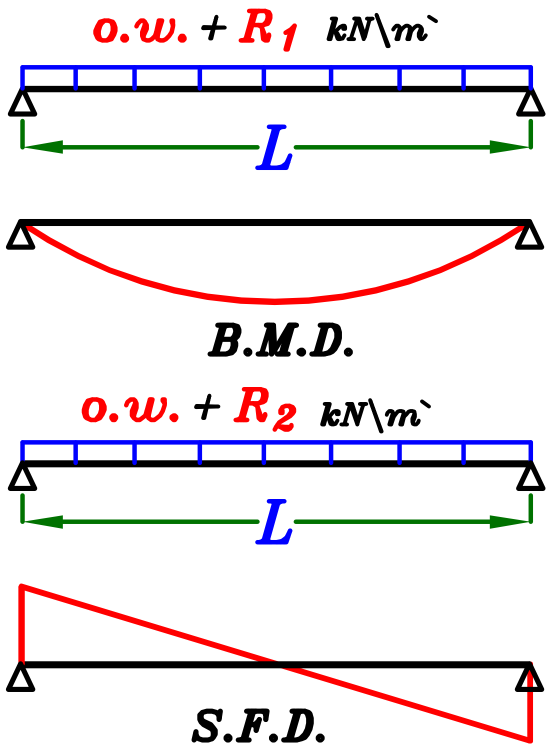
Double Cantilever عند وجود
متساويه فى الطول نعمل حالات تحميل
فنضع **T.L.** على أى منهما

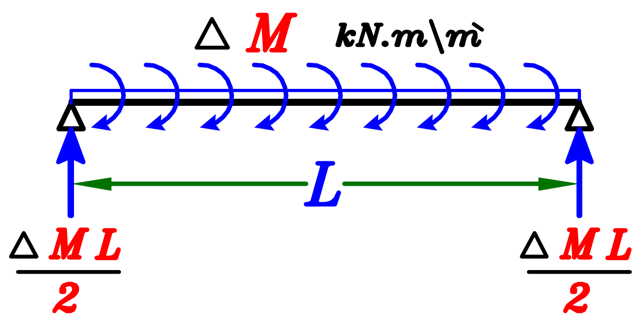


$$\Delta M = M_1 - M_2$$

Load

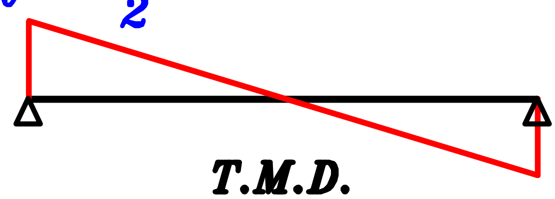
Moment



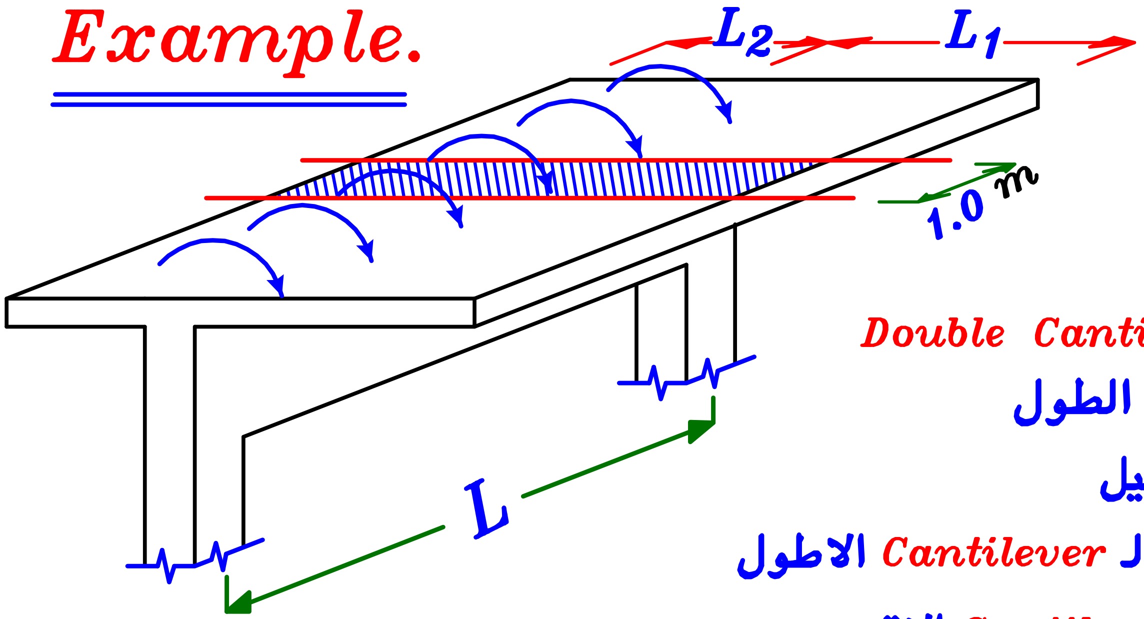


فى التصميم يجب التصميم على
ال **Shear** و ال **Torsion** من نفس حاله التحميل

$$M_t = \frac{\Delta M L}{2}$$

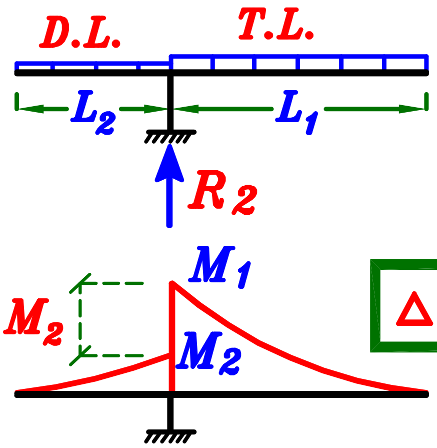


Example.

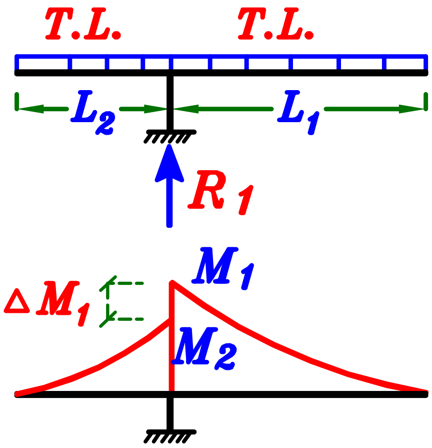


عند وجود Double Cantilever
غير متساويه فى الطول
نعمل حالات تحميل
فنضع T.L. على ال Cantilever الاطول
و D.L. على ال Cantilever الاقصر

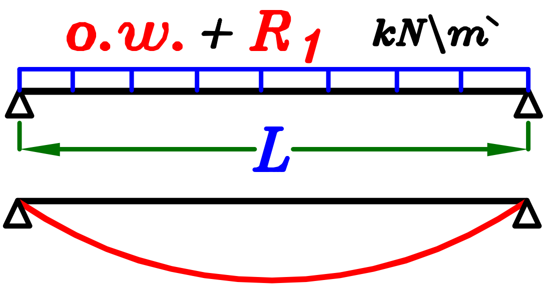
Strip in the slab.



$$\boxed{\Delta M = M_1 - M_2}$$

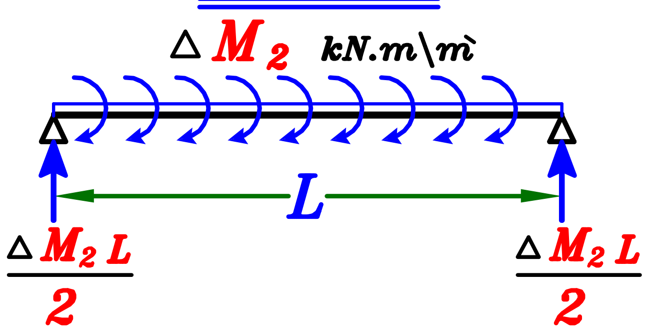


Load

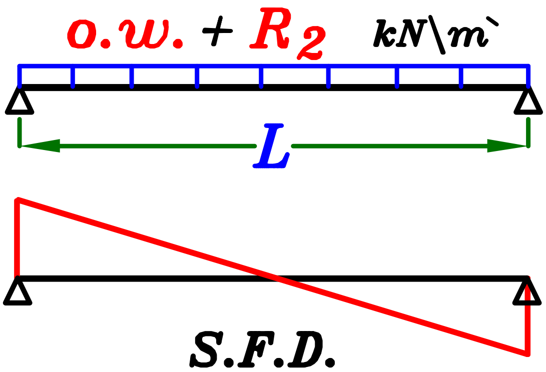


B.M.D.

Moment

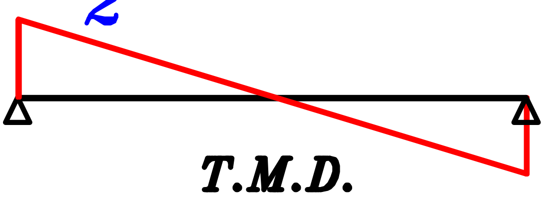


فى التصميم يجب التصميم على
ال Shear و ال Torsion من نفس حاله التحميل



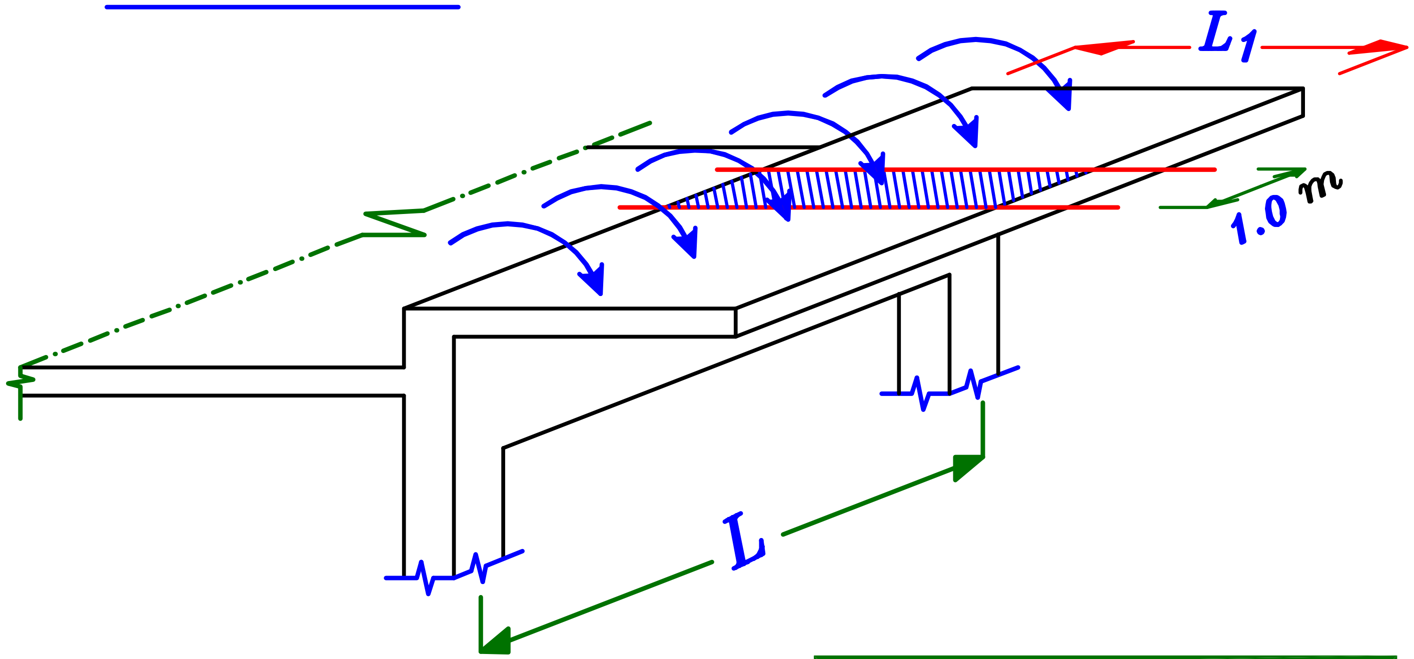
S.F.D.

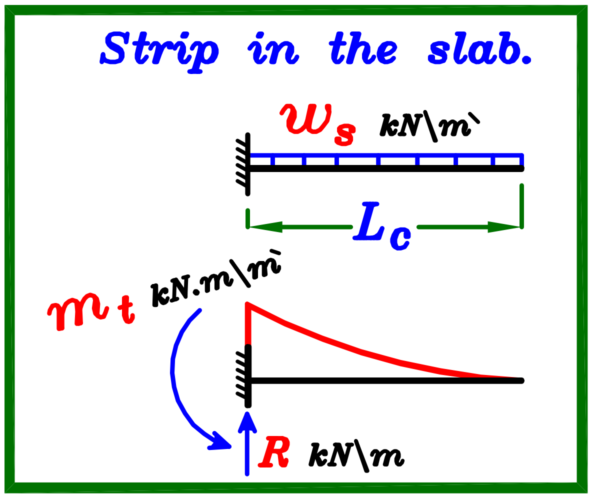
$$M_t = \frac{\Delta M_2 L}{2}$$



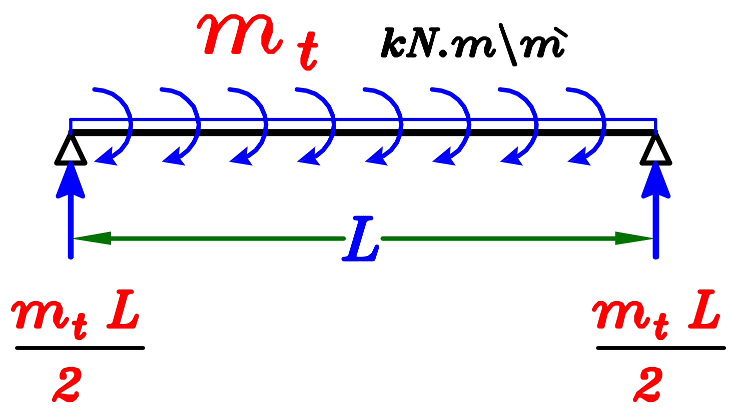
T.M.D.

Example.

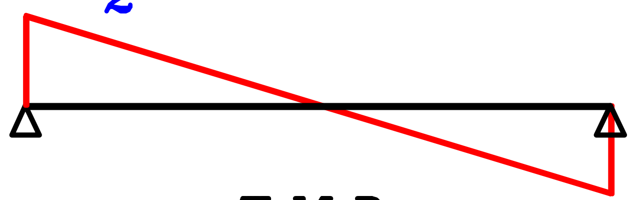




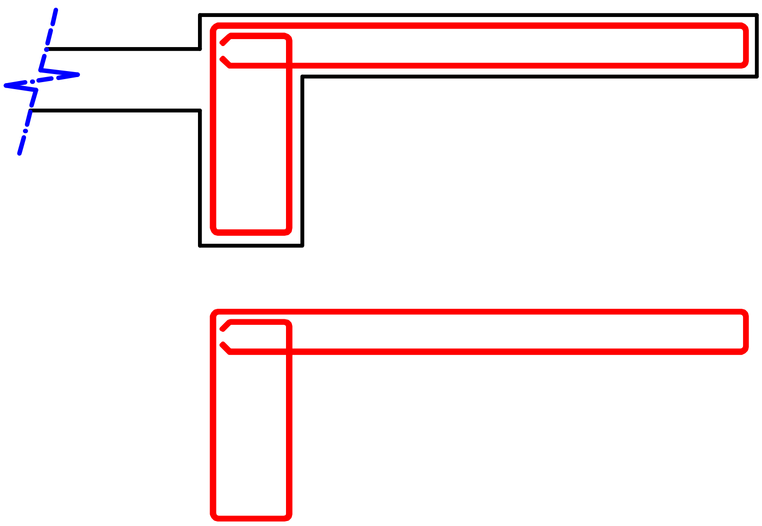
Moment



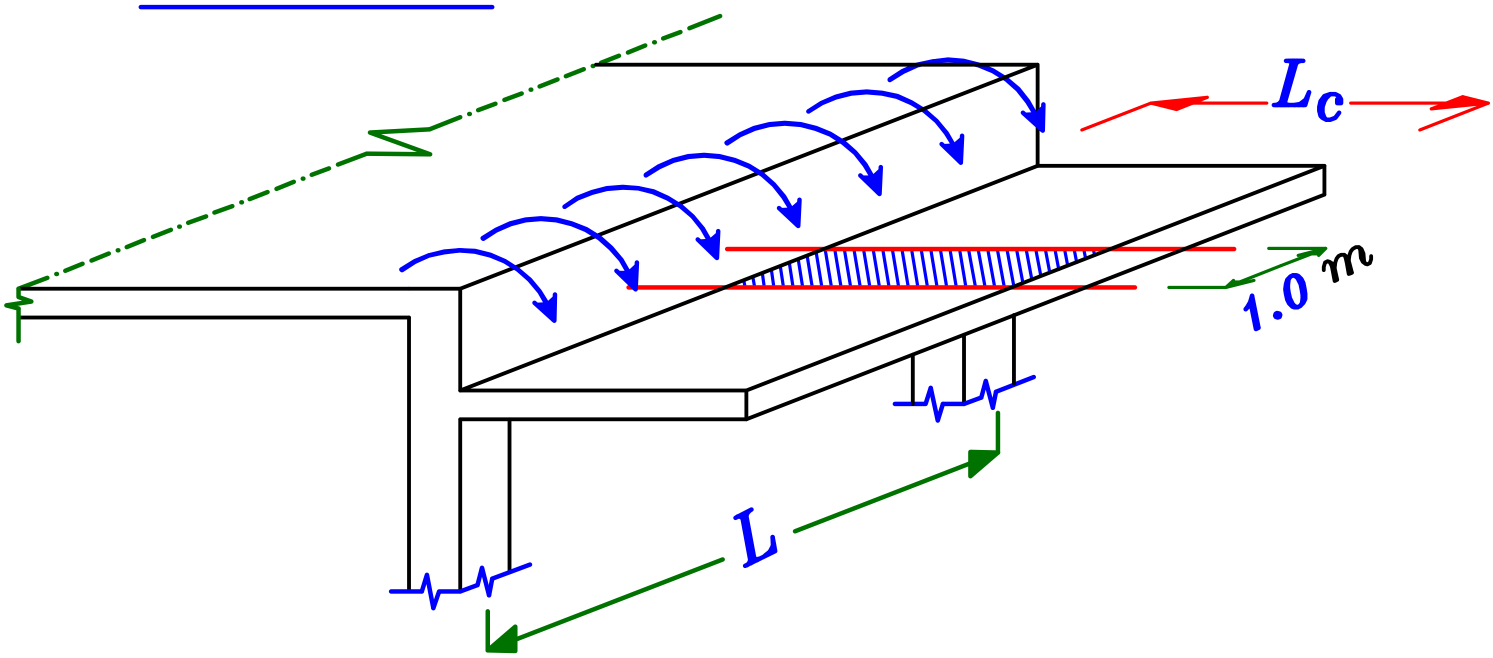
$$M_t = \frac{m_t L}{2}$$



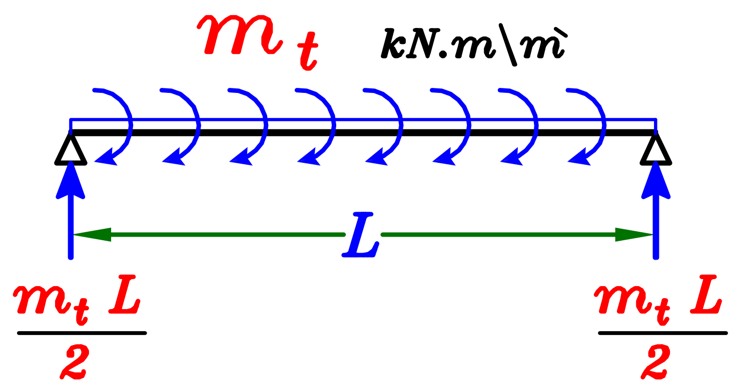
T.M.D.

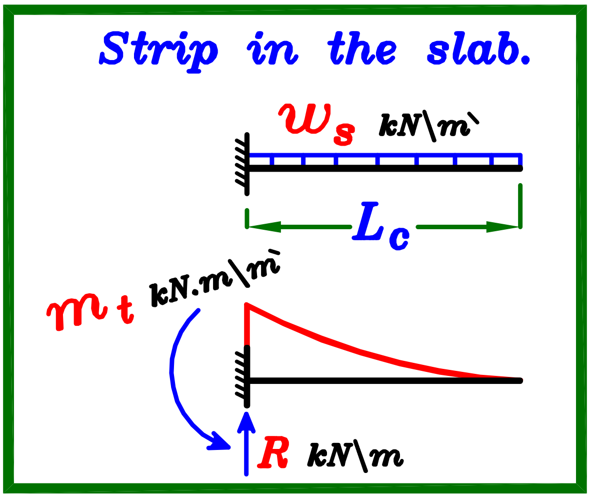


Example.

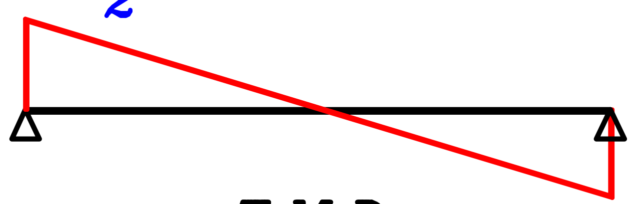


Moment

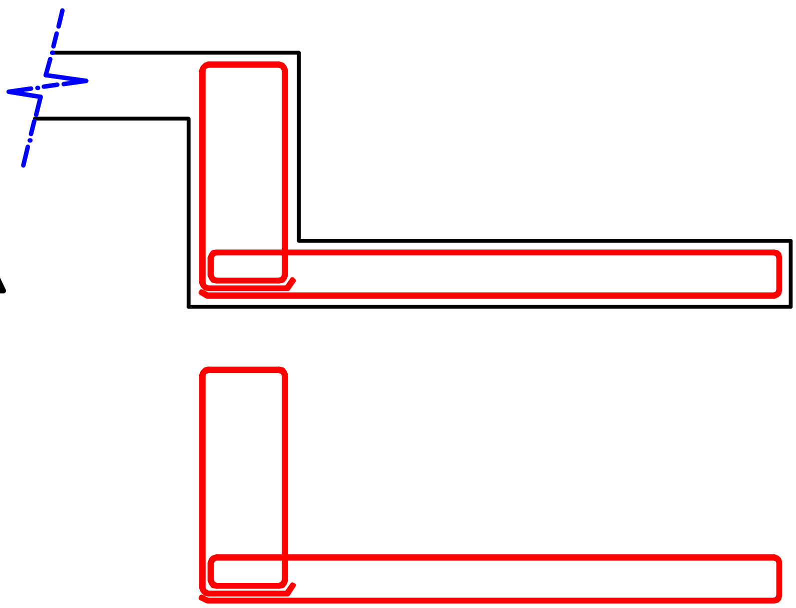




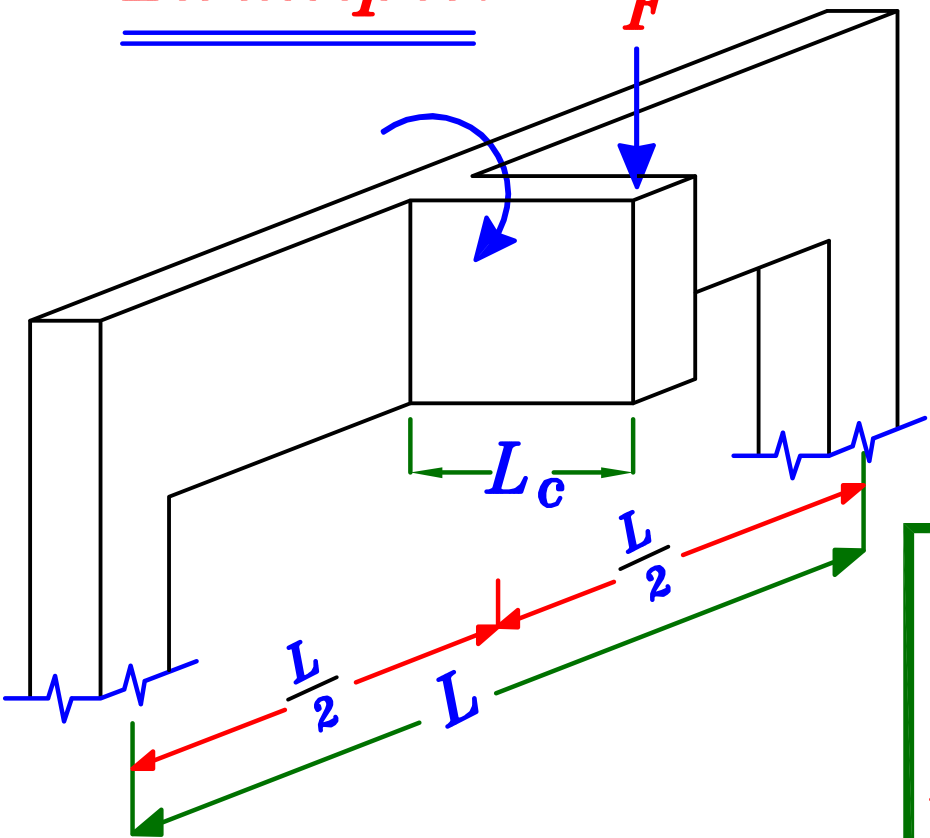
$$M_t = \frac{m_t\,L}{2}$$

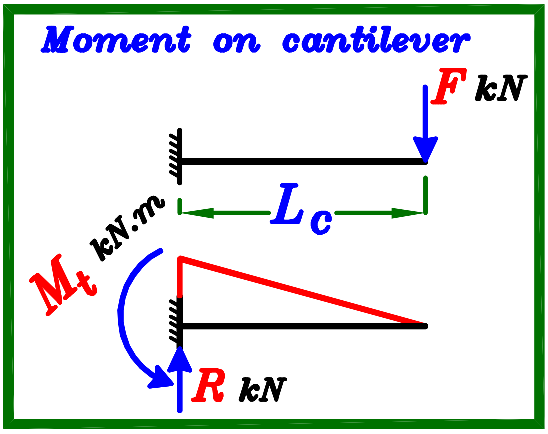


T.M.D.

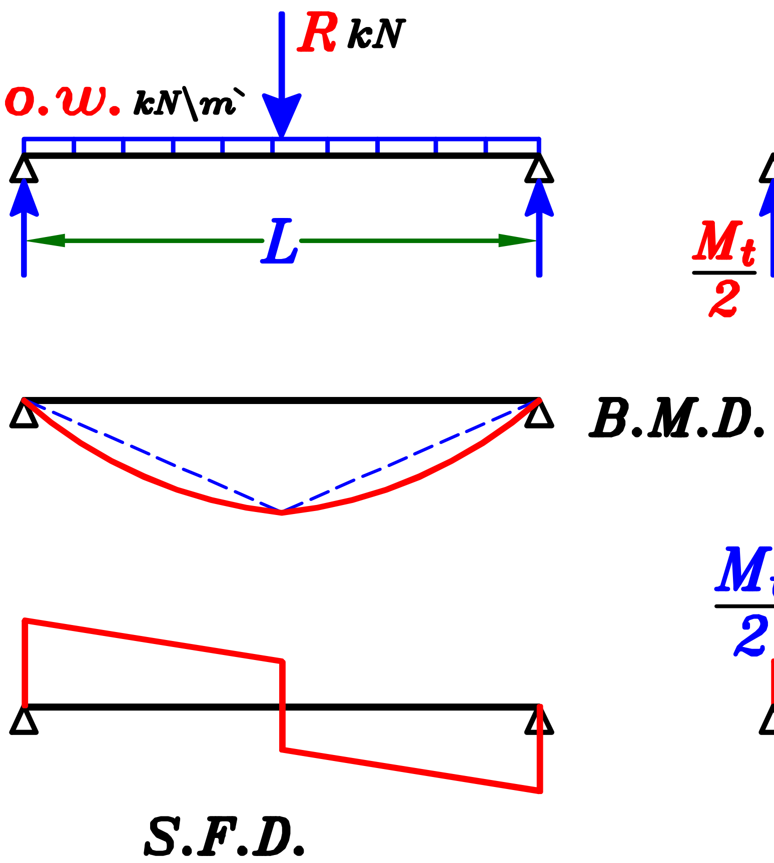


Example.

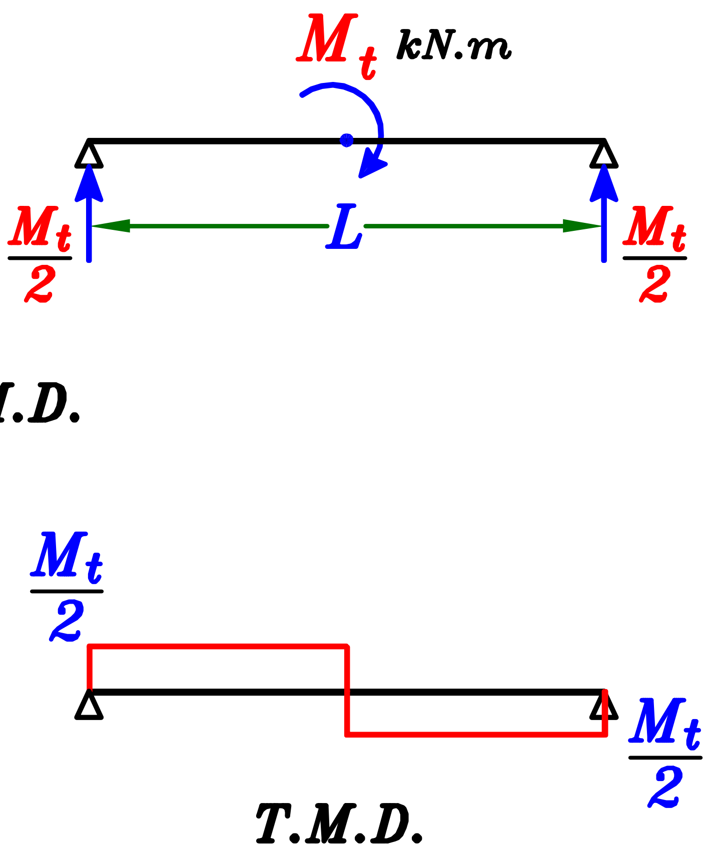




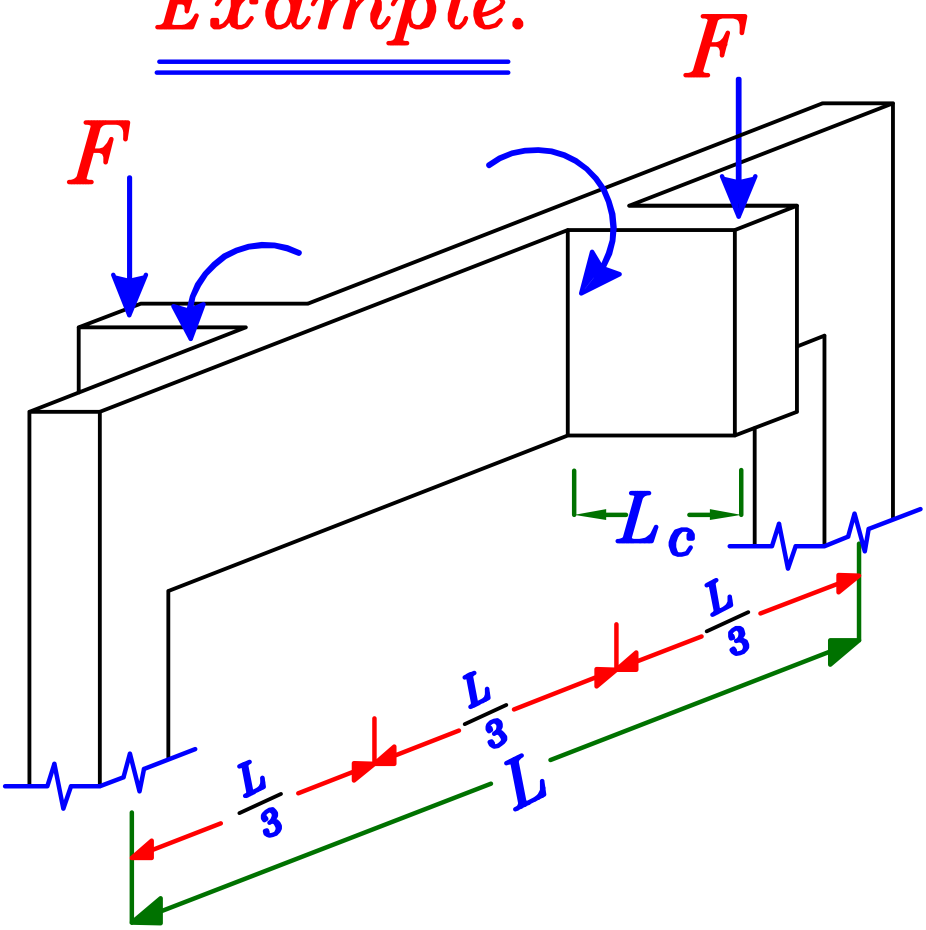
Load

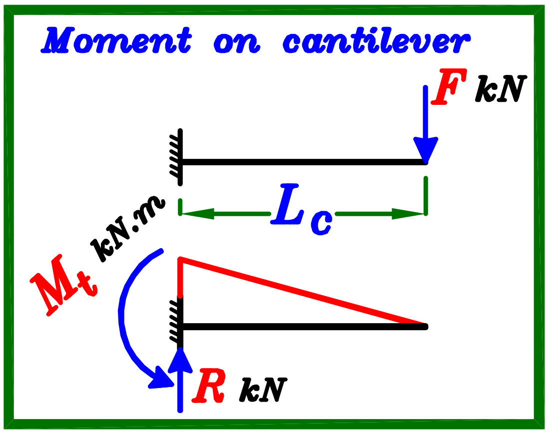


Moment

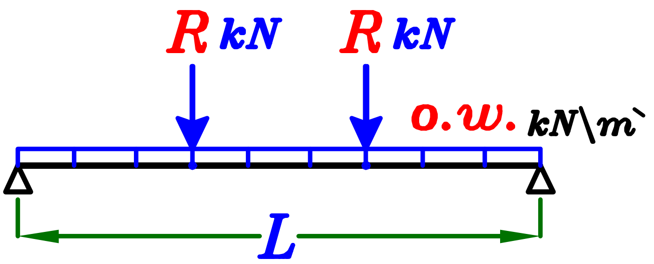


Example.

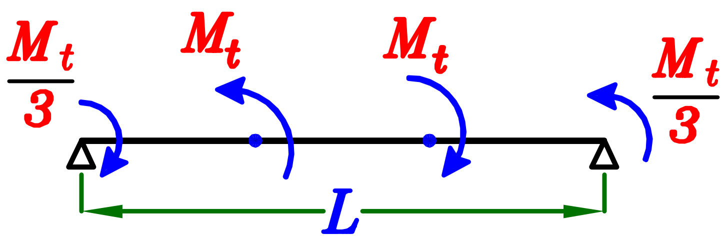


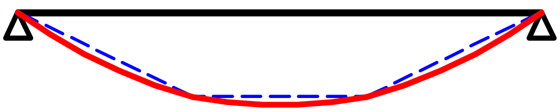


Load

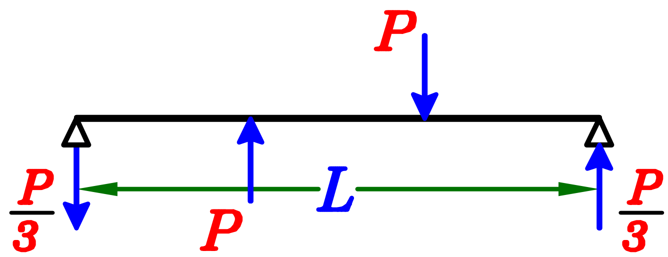


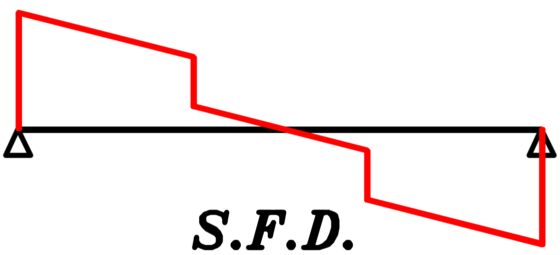
Moment



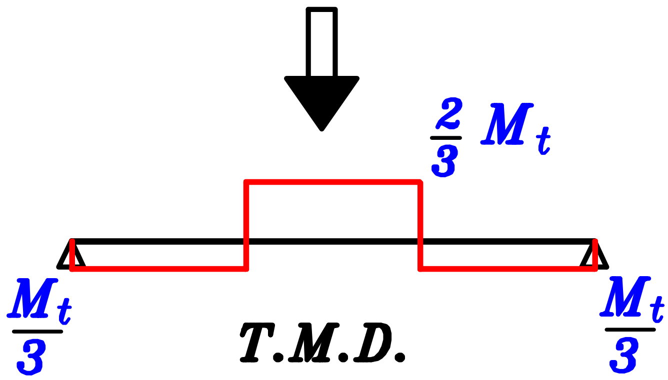


B.M.D.



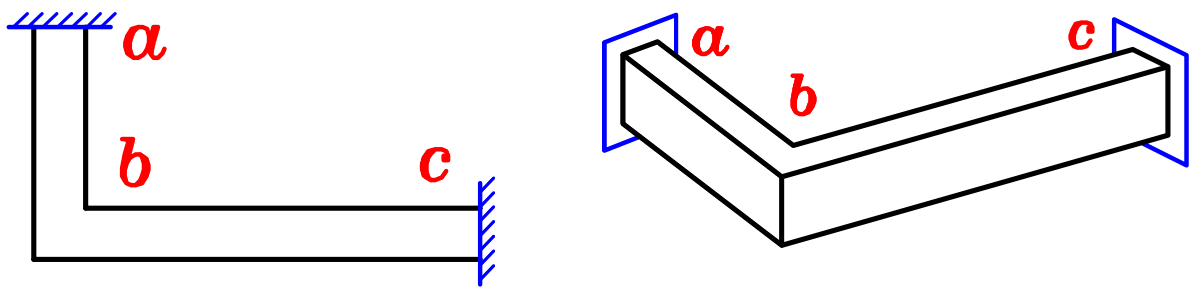


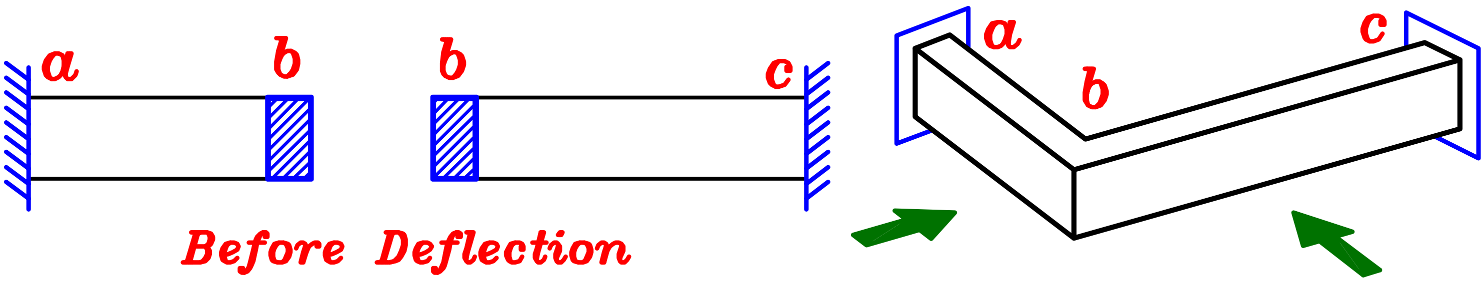
S.F.D.

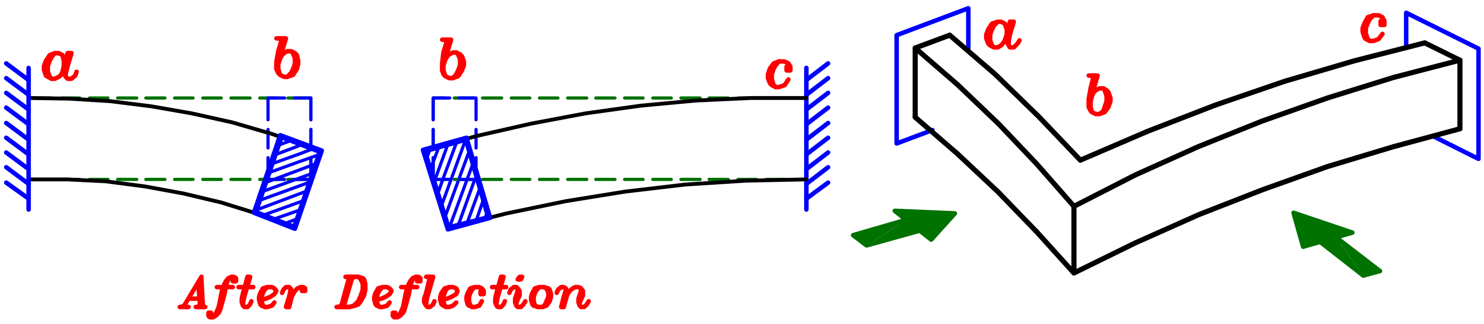


T.M.D.

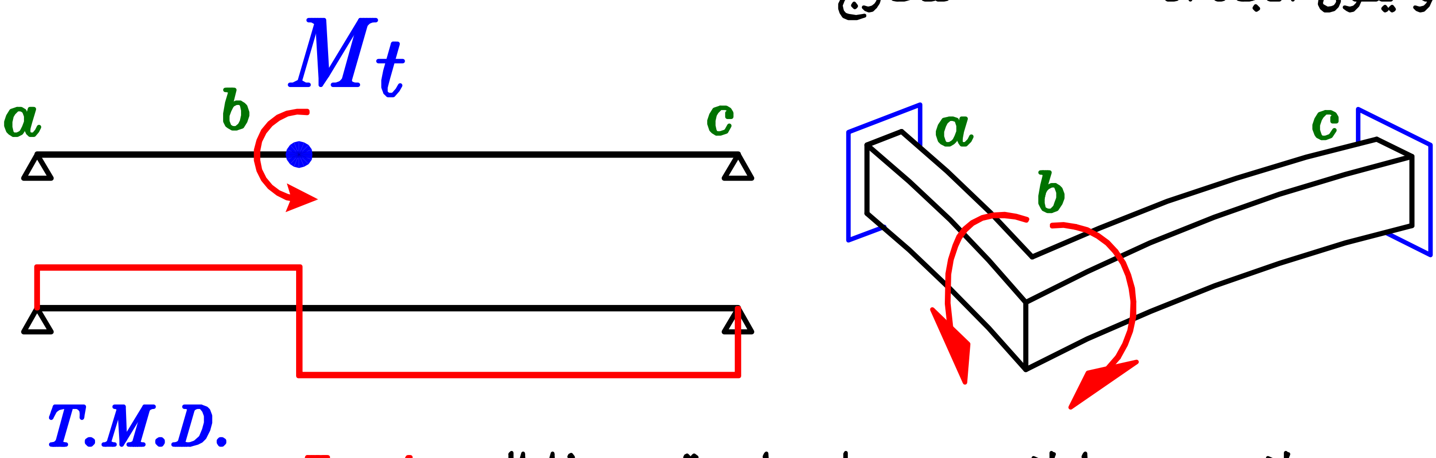
Segmented Beam. الكمرات التى بها كسرات أفقيه





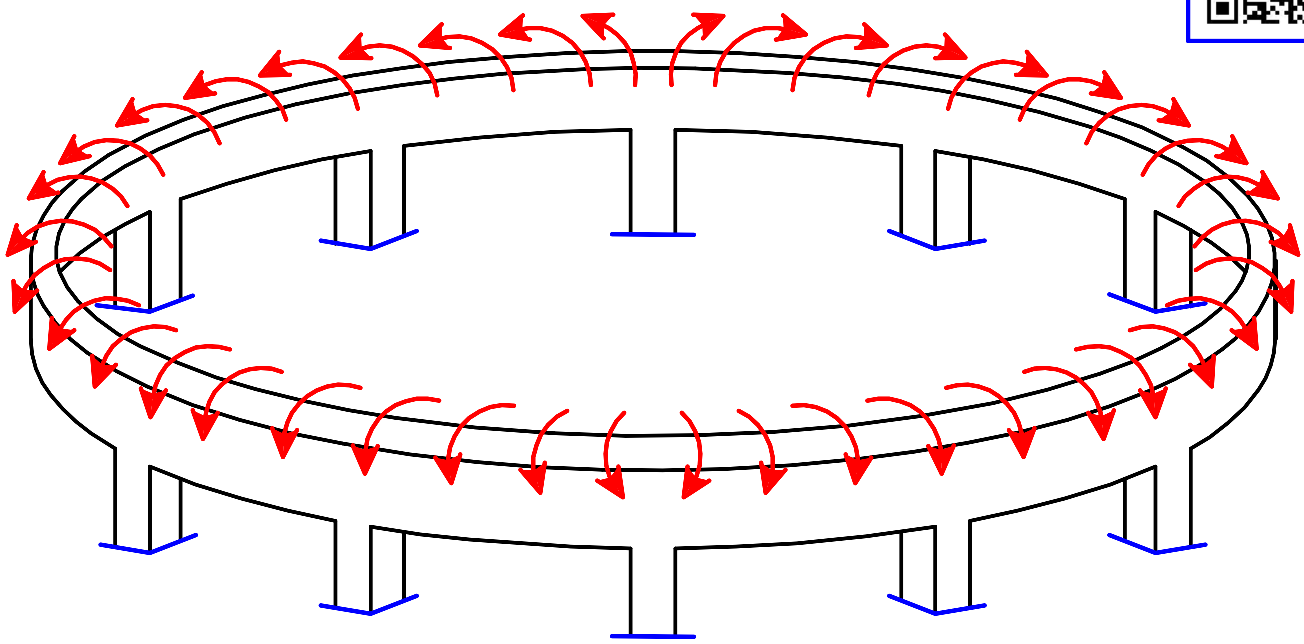


الكمرات التى بها كسرات أفقيه يكون عليها ***Concentrated torsional Moment***
لانه يحدث انحناء لكل جزء من الكمره عند حدوث ال ***Deflection***
مما يعمل على دوران القطاع للجزء الاخر من الكمره .
و يكون اتجاه ال ***Torsion*** للخارج



لا توجد معادلات يدويه لحساب قيمه هذا ال ***Torsion***
لذا عند حساب قيمته نحتاج لاستخدام برامج الكمبيوتر .

Circular Beams.



الكمرات الدائريه مثل الكمرات التى بها كسرات أفقيه و لكن ال **Torsion**

فيها **Distributed torsional Moment**

لحساب ال **Bending Moment & Shear Force & Torsional Moment**

المؤثرين على الكمره ممكن استخدام الجدول التالى

Old Tables Page 120

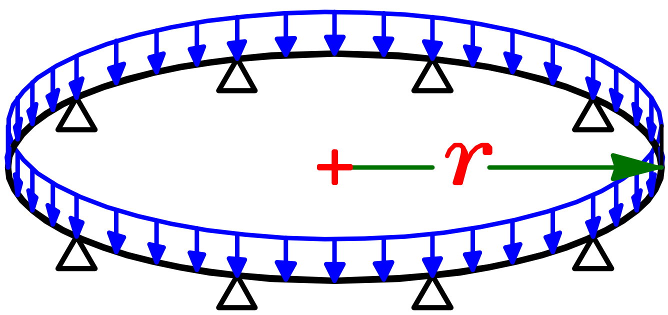
$$\boxed{P = w * 2\pi r}$$

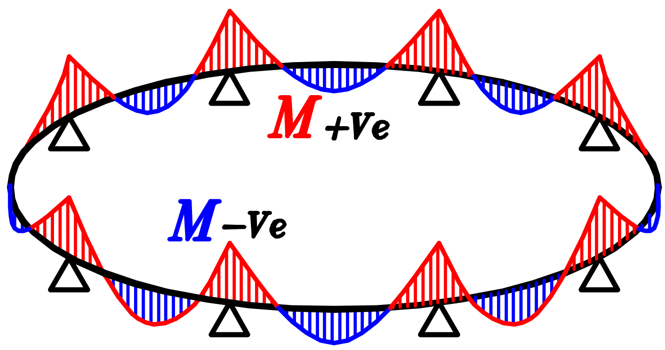
P = Total load on the beam. (kN)

w = Load per meter. (kN/m')

r = Radius of the beam. (m)

n = Number of supports.





Data for Design of Reinforced Concrete Structures

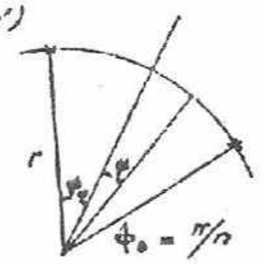
1. Circular Beams

Supported on a number of supports (n) at equal distance under uniformaly dist^{ed} load (pt/m')

$$M = pr^2 \left[\pi/n \frac{\cos\phi}{\sin\phi_0} - 1\right]$$

$$M_t = -pr^2 \left[\pi/n \frac{\sin\phi}{\sin\phi_0} - \phi\right]$$

$$Q = -p.r.\phi$$



$\phi_0 = \pi/n$

Table of extreme values

$P = 2\pi r.p$

Number of Supports (n)	Load on each column R	Max. Shearing force Q max.	Max. Bending M: At center of span M (+)	Max. Bending M: over Support M (-ve)	Max. Torsion-al moment M_t	Centeral angle between Axis of Supports & Sec. of max. (M_t)
4	P/4	P/8	.0176 Pr	-.0322 Pr	.0053 Pr	19° 21'
6	P/6	P/12	.0075 Pr	-.0148 Pr	.0015 Pr	12° 44'
8	P/8	P/16	.0042 Pr	-.0083 Pr	.0006 Pr	9° 33'
10	P/10	P/20	.0032 Pr	-.0052 Pr	.0004 Pr	7° 36'
12	P/12	P/24	.0019 Pr	-.0037 Pr	.0002 Pr	6° 21'

No. of supports	Load on each support	Max. Shearing Force	Max. Bending Moment: at C.L. of Span	Max. Bending Moment: Over C.L. of Column	Max. Torsional Moment	Centeral angel
n	R	$Q_{max.}$	M +Ve	M −Ve	$M_{t\,max.}$	θ
4	P/4	P/8	0.0176 Pr	− 0.0322 Pr	0.0053 Pr	19° 21'
6	P/6	P/12	0.0075 Pr	− 0.0148 Pr	0.0015 Pr	12° 44'
8	P/8	P/16	0.0042 Pr	− 0.0083 Pr	0.0006 Pr	9° 33'
10	P/10	P/20	0.0032 Pr	− 0.0052 Pr	0.0004 Pr	7° 36'
12	P/12	P/24	0.0019 Pr	− 0.0037 Pr	0.0002 Pr	6° 21'

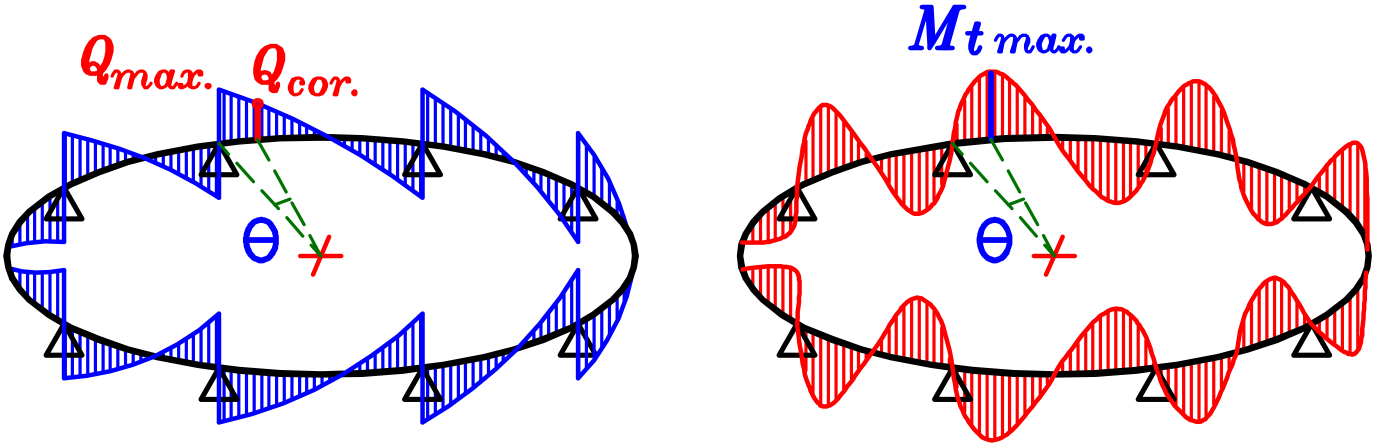
ال (θ) **Centeral angel** هى الزاويه المقاسه من ال **Support** حتى النقطه التى يوجد عندها **max. Torsional moment**

ملاحظات هامه .

١- ال (θ) *Centeral angel* هى الزاويه المقاسه من ال *Support* حتى النقطه التى يوجد عندها *max. Torsional moment*

أى أن ال *Section* الذى يوجد عنده *max. Torsional moment* مكانه غير ال *Section* الذى يوجد عنده *max. Shear Force*

لذا عند تصميم الكانات لنتحمل *Shear + Torsion* نحدد قيمه $Q_{corresponding}$ و هى قيمه ال *Shear Force* عند ال *Section* الذى يوجد عنده *max. Torsion*



S.F.D.

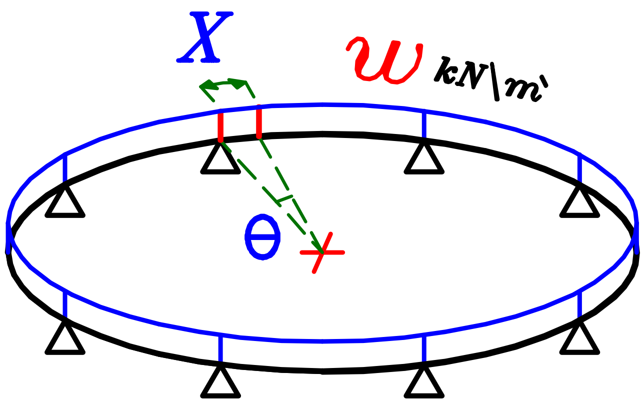
T.M.D.

Radian

$$X = r * \theta = r * \theta * \frac{\pi}{180}$$

$$\boxed{X = r * \theta * \frac{\pi}{180}}$$

$$\boxed{Q_{cor.} = Q_{max} - w * X}$$



ممكن للتسهيل تصميم القطاع على $(M_{t\,max.} \,, Q_{max})$

٢- اذا كان عدد ال *Supports* اكبر من او يساوى ١٢ $(n \geq 12)$ فمن الممكن :

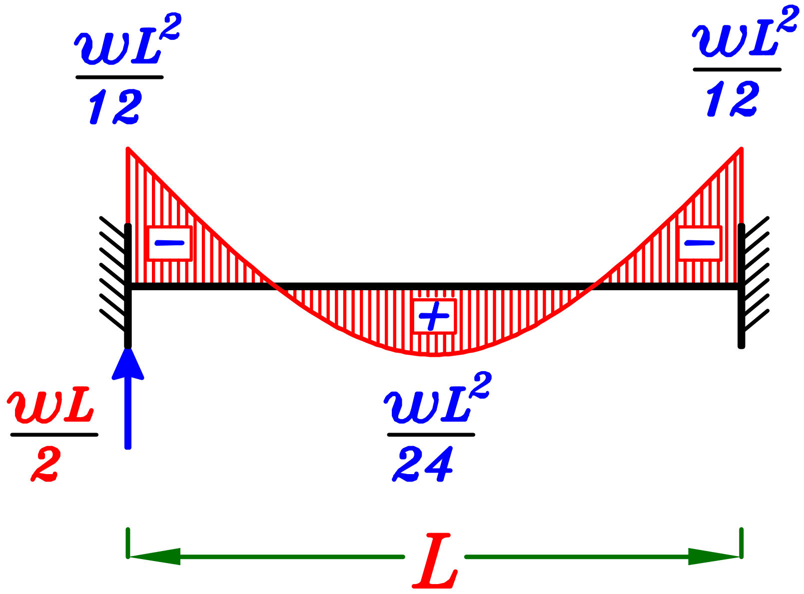
أ- نهمل عزم الالتواء (M_t) لان قيمته ستكون صغيره جدا .

ب- ممكن حساب ال *max. Shear Force* & *max. Bending Moment* كالاتى :

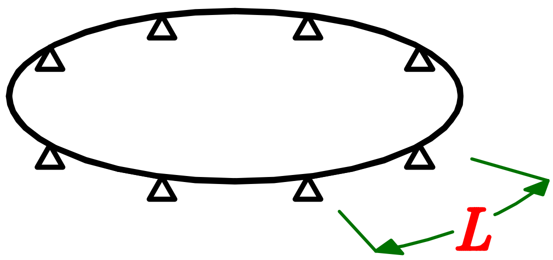
$$\boxed{max.\ M_{-ve} = \frac{wL^2}{12}}$$

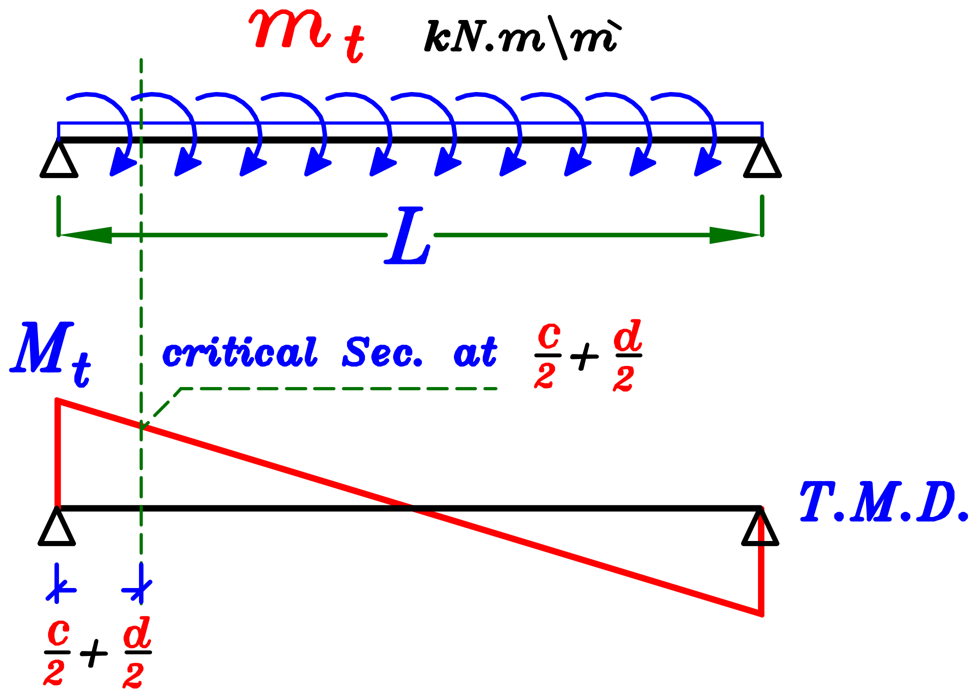
$$\boxed{max.\ M_{+ve} = \frac{wL^2}{24}}$$

$$\boxed{Q_{max.} = \frac{wL}{2}}$$



where $\boxed{L = \frac{2\pi r}{n}}$





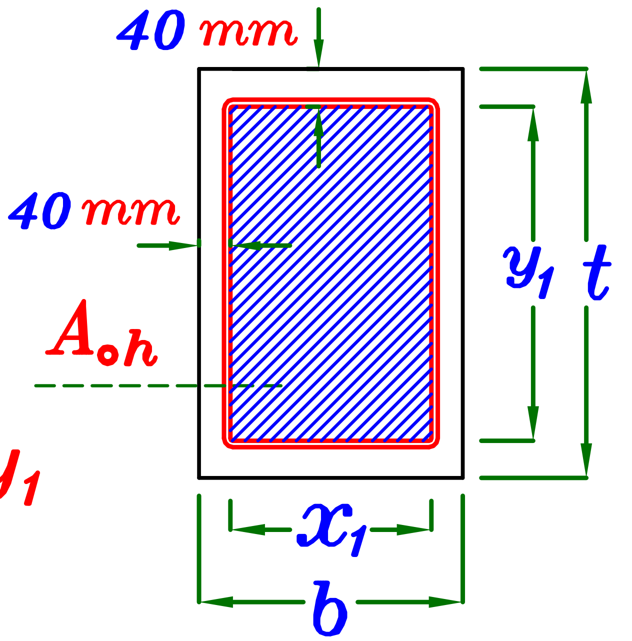
$$\boxed{q_{tu} = \frac{M_{tu}}{2\, A_o\, t_e}} \quad (N\backslash mm^2)$$

Where:

* q_{tu} ($N\backslash mm^2$) = Actual Shear Stress due to Torsional Moment.
* M_{tu} ($N.mm$) = Torsional Moment at Critical Section.
* A_{oh} (mm^2) = Torsion المساحه الداخليه للكانه المقاومه لل
* A_o (mm^2) = $0.85 * A_{oh}$
* P_h (mm) = Torsion محيط الكانه المقاومه لل
* t_e (mm) = $\dfrac{\text{المساحه الداخليه للكانه}}{\text{محيط الكانه}} = \dfrac{A_{oh}}{P_h}$

* $y_1 = t - 2\,Cover \simeq t - 80\ mm$

* $x_1 = b - 2\,Cover \simeq b - 80\ mm$



For R-Sec.

$$A_{oh} = \text{المساحه الداخليه للكانه} = x_1 * y_1$$

$$P_h = \text{محيط الكانه} = 2\,(x_1 + y_1)$$

$$t_e = \frac{\text{المساحه الداخليه للكانه}}{\text{محيط الكانه}} = \frac{x_1 * y_1}{2\,(x_1 + y_1)}$$

$$\therefore \boxed{q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{M_{tu}\,(x_1 + y_1)}{0.85\,(x_1^2 * y_1^2)}}$$

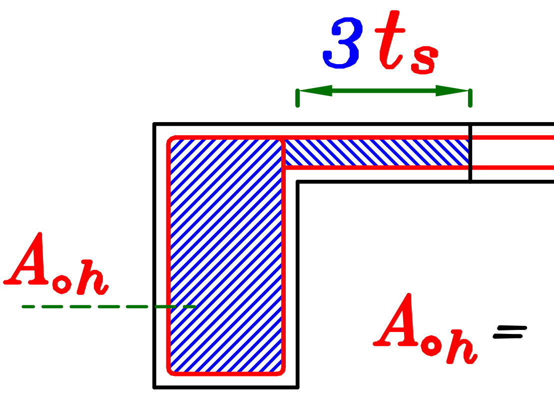
For R-Sec. only

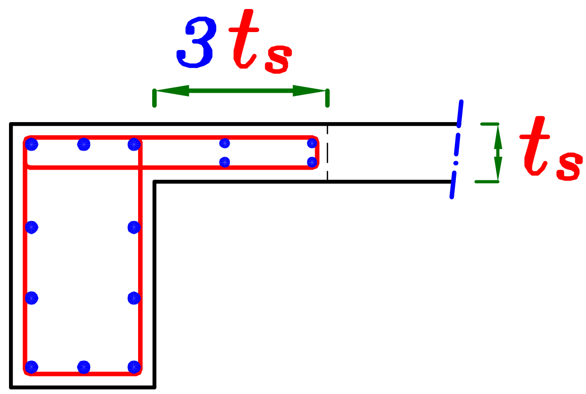
For L-Sec.

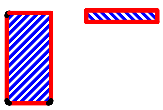
عند وجود بلاطه مع الكمره من الممكن أن نعتبر أن جزء من البلاطه يقاوم

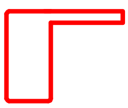
الـ Torsion مع الكمره . و هذا الجزء يساوى تقريبا $3\,t_s$

بشرط ان يوضع فى هذا الجزء كانات لمقاومه الـ Torsion

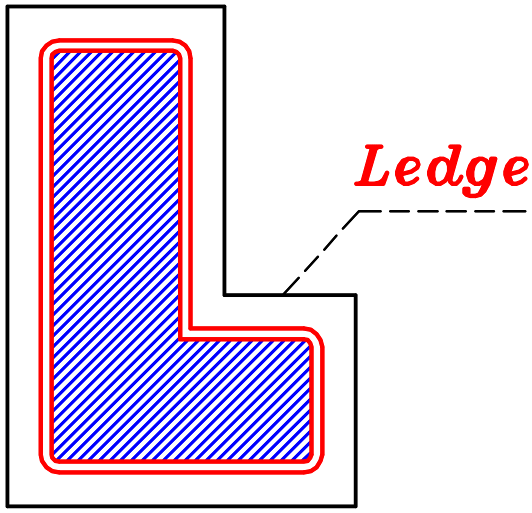


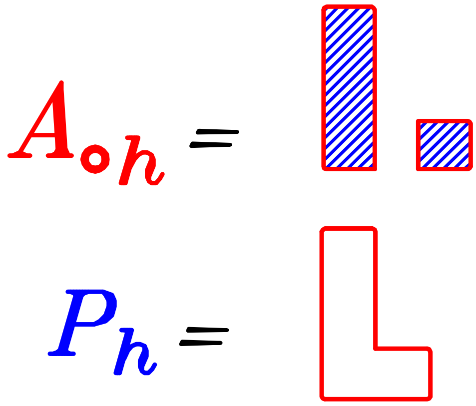


$A_{oh} =$ 

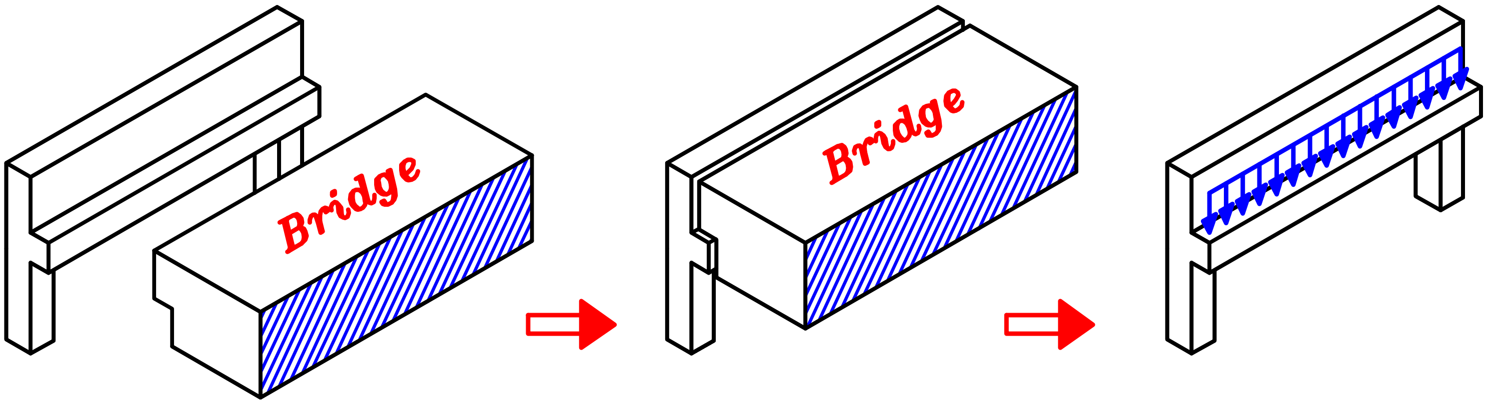
$P_h =$ 

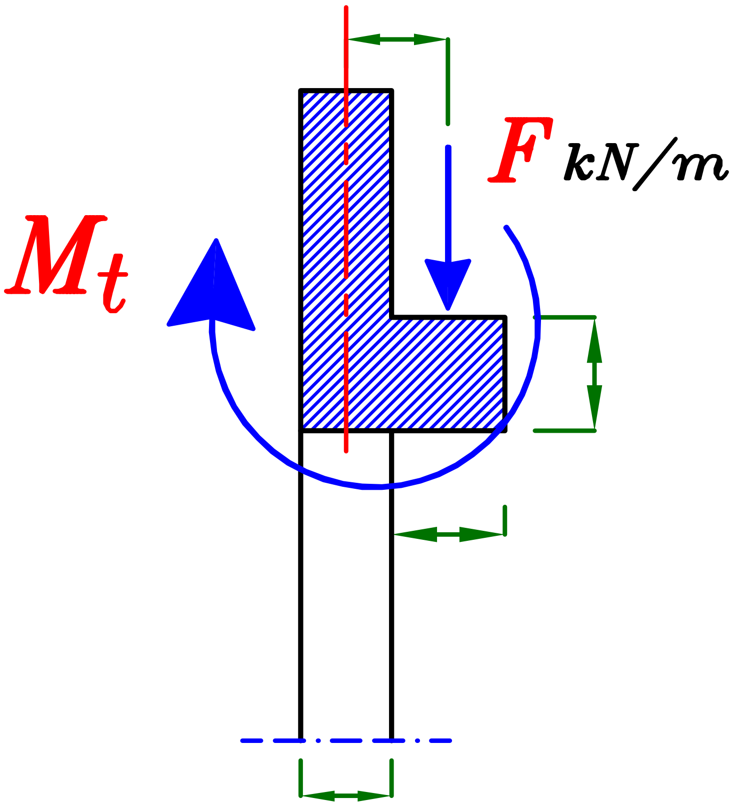
For Ledge Beam كمره ذات نتؤ



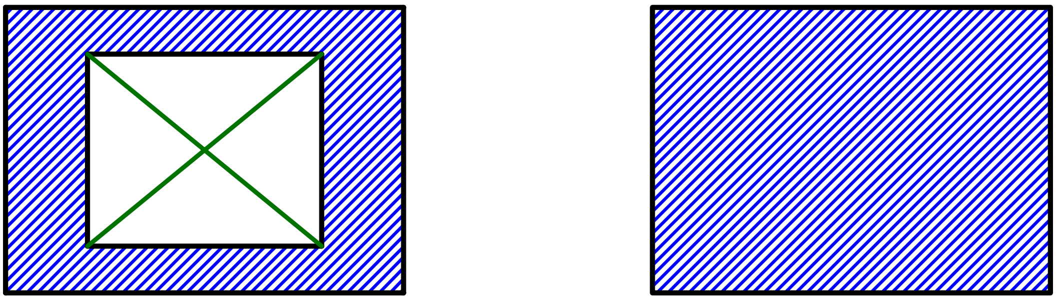


عاده تستخدم *Ledge Beam* فى الكبارى



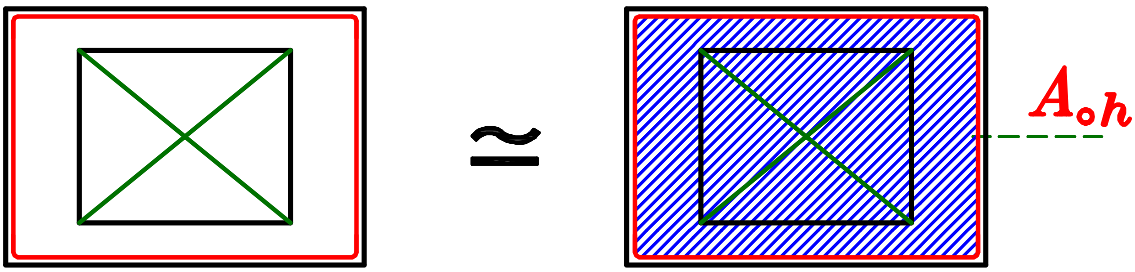


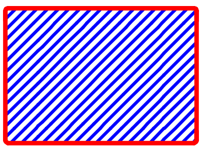
لا ن أكبر تأثير لل Torsion يكون على الاطراف الخارجيه
و ال Torsion stress فى المنتصف يكون قليل
لذا تعتبر مقاومه القطاعات المفرغه من المنتصف لل Torsion تقريبا تساوى مقاومه القطاعات المصمته .

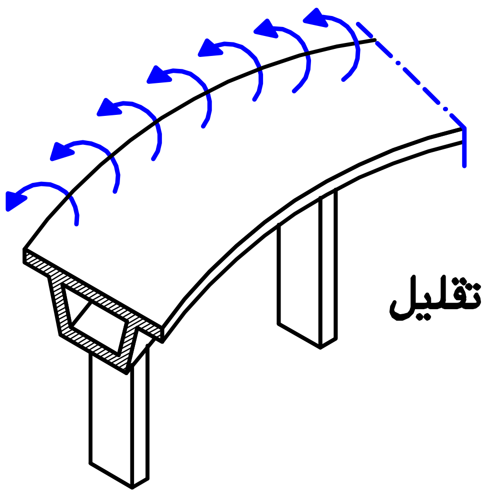


مقاومه ال Torsion ≃ مقاومه ال Torsion

لذا فى القطاعات ال Box Sections عند حساب ال Torsion نعتبره مثل القطاعات المصمته .

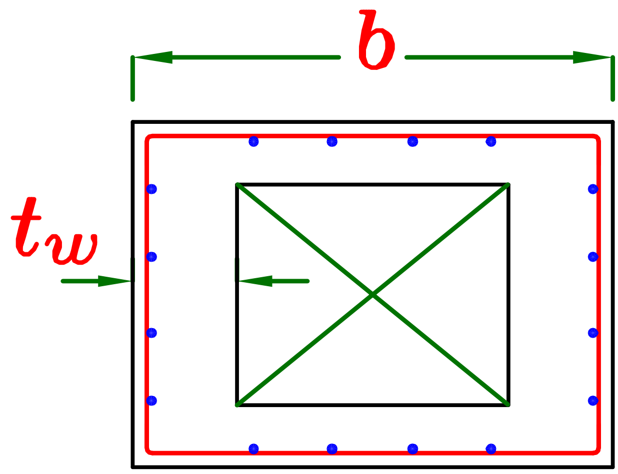


$A_{oh} =$  , $P_h =$ 



من اشهر تطبيقات ال Box Sections يكون فى الكبارى التى بها منحنيات
لان مقاومتها لل Torsion كبيره و فى نفس الوقت وزنها خفيف فيقل ال B.M. مما يعمل على تقليل التسليح و بالتالى توفير فى السعر .

فى القطاعات الصندوقيه .

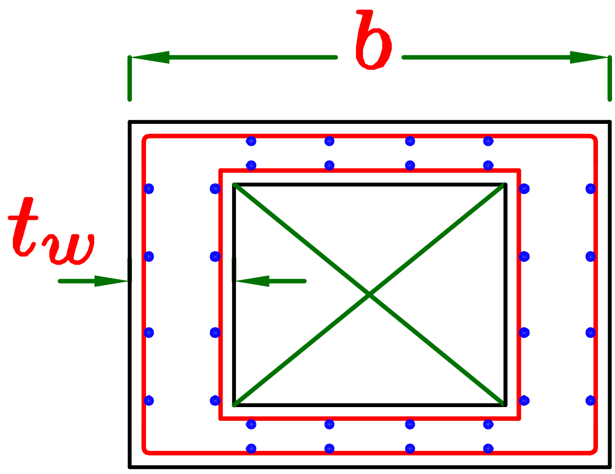


IF $\boxed{t_w > \frac{b}{6}}$

نأخذ قيمه P_h هو طول الكانات
على المحيط الخارجى فقط

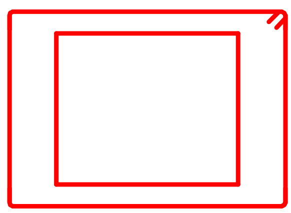
$P_h =$ 

يتم وضع اسياخ ***Longitudinal Bars***
على المحيط الخارجى فقط



IF $\boxed{t_w \leqslant \frac{b}{6}}$

نأخذ قيمه P_h هو طول الكانات
على المحيط الخارجى و الداخلى للقطاع

$P_h =$ 

يتم وضع اسياخ ***Longitudinal Bars***
على المحيط الخارجى و الداخلى للقطاع

Design For Shear + Torsion.

Actual Stresses due to Shear Force. q_u

$$\boxed{q_u = \frac{Q}{b\,d}}$$

Actual Stresses due to Torsional Moment. q_{tu}

$$\boxed{q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e}}$$

---

min. allowable stresses due to Shear q_{cu}

$$\boxed{q_{cu} = (0.24)\sqrt{\frac{F_{cu}}{\gamma_c}}}$$

min. allowable stresses due to Torsion q_{tu}

$$\boxed{q_{t_{min}} = (0.06)\sqrt{\frac{F_{cu}}{\gamma_c}}}$$

---

max. allowable shear stresses $q_{u\,max}$

$$\boxed{q_{u\,max} = (0.70)\sqrt{\frac{F_{cu}}{\gamma_c}}}$$

IF $\sqrt{q_u^2 + q_{tu}^2} > q_{u\,max} \longrightarrow$ Increase Dimensions

For Box Sections only.

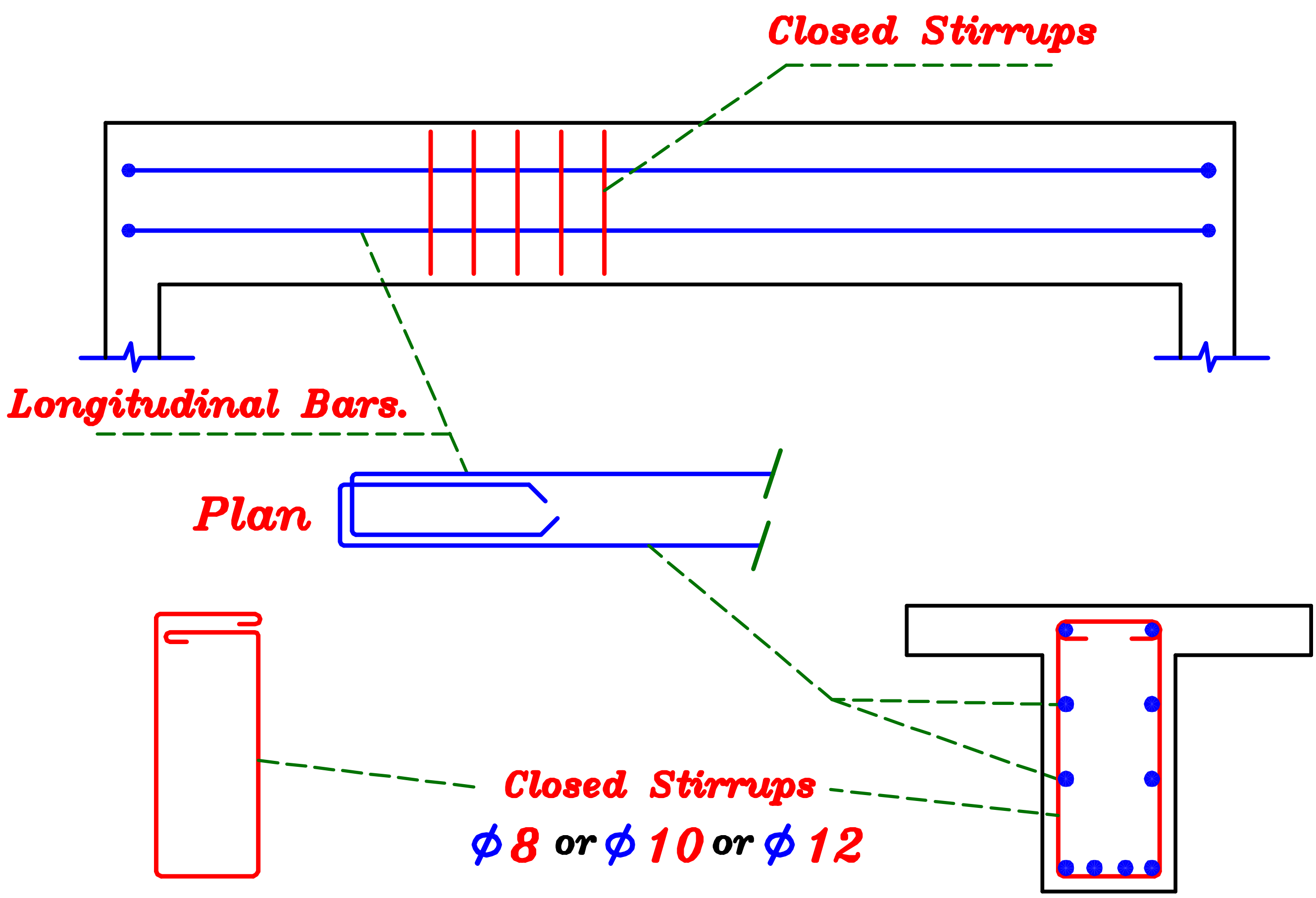
IF $q_u + q_{tu} > q_{u\,max} \longrightarrow$ Increase Dimensions

IF $\sqrt{q_u^2 + q_{tu}^2} \leq q_{u\,max}$

	q_u	q_{tu}	RFT.
1	$q_u < q_{cu}$	$q_{tu} < q_{t\,min}$	Use Stirrups $5\phi8\backslash m'$
2	$q_u > q_{cu}$	$q_{tu} < q_{t\,min}$	Use RFT. to resist $\left(q_u - \frac{q_{cu}}{2}\right)$
3	$q_u < q_{cu}$	$q_{tu} > q_{t\,min}$	Use RFT. to resist (q_{tu})
4	$q_u > q_{cu}$	$q_{tu} > q_{t\,min}$	Use RFT. to resist $\left(q_u - \frac{q_{cu}}{2}\right) + (q_{tu})$

How to Resist Torsion ??

1. Closed Stirrups. — ١ كانات مغلقة .
2. Longitudinal Bars. — ٢ أسياخ طوليه .



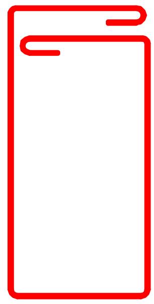
Case ③ $q_u < q_{cu}$, $q_{tu} > q_{t\,min}$

Use Shear RFT. to resist Shear Stresses $\left(q_{tu} - \frac{q_{t\,min}}{2}\right)$ *applied From Torsional moment.*

① Closed Stirrups.

$$\boxed{A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\ \left(\frac{F_y}{\gamma_s}\right)}}$$

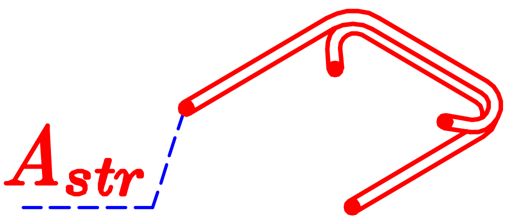
حفظ



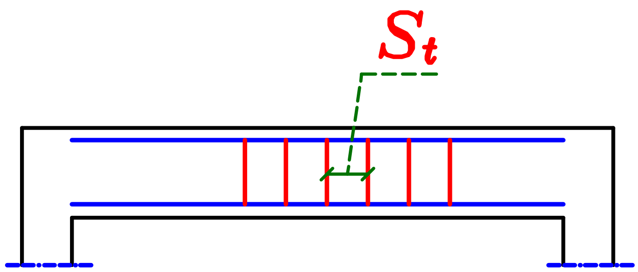
Closed Stirrup

Where:

* A_{str} مساحه مقطع سيخ الكانه



ϕ	A_{str}
ϕ 8	50.3 mm^2
ϕ 10	78.5 mm^2
ϕ 12	113 mm^2



ملحوظه .

- ممكن إستخدام كانات حتى ϕ 12 فى ال Torsion

- كانات ال Torsion تكون الكانات الخارجيه فقط .

* S_t المسافه الطوليه بين كانات ال Torsion

$$S_t = (100\ mm \longrightarrow 200\ mm)$$

In the equation choose $\phi \longrightarrow A_{str} = \checkmark$

Then get $S_t = (100\ mm \longrightarrow 200\ mm)$

IF $S_t \geqslant 200\ mm \xrightarrow{use} 5\phi \checkmark \backslash m'$

IF $S_t < 100\ mm$ Choose bigger ϕ

IF $100\ mm < S_t < 200\ mm \xrightarrow{Get}$ No of stirrups $\backslash m' = \frac{1000}{S_t}$

---

min. Stirrups.

ملاحظات .

$$\boxed{\frac{2A_{str}}{b * S} \nless \frac{0.4}{F_y}} \longrightarrow A_{str_{min}} = \frac{0.2\,(b * S)}{F_y}$$

حيث F_y للكانات

$$S_{max.} = \frac{P_h}{8}$$

$$= 200\ mm$$

الاصغر

② Longitudinal Bars.

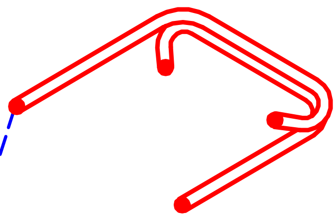
$$\boxed{A_{sl} = \frac{A_{str} * P_h}{S_t}\left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right)}$$

Where:

* A_{sl} مجموع مساحه مقطع الأُسياخ الطوليه كلها.

* A_{str} مساحه مقطع سيخ الكانه.

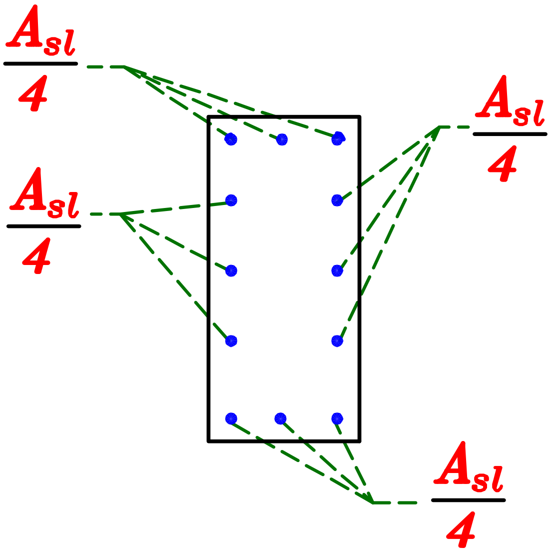
A_{str}



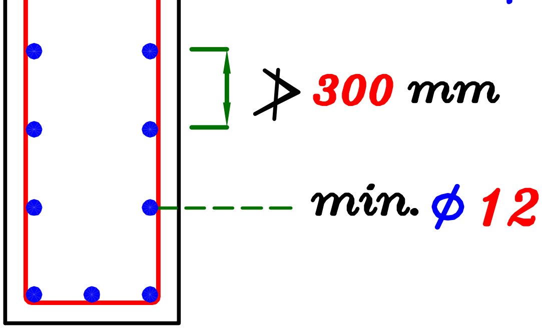
* $F_{y\,str.} = F_y$ For stirrups. $\simeq$ 240 $N\backslash mm^2$
* $F_{y\,L.b.} = F_y$ For Longitudinal bars. $\simeq$ 360 $N\backslash mm^2$

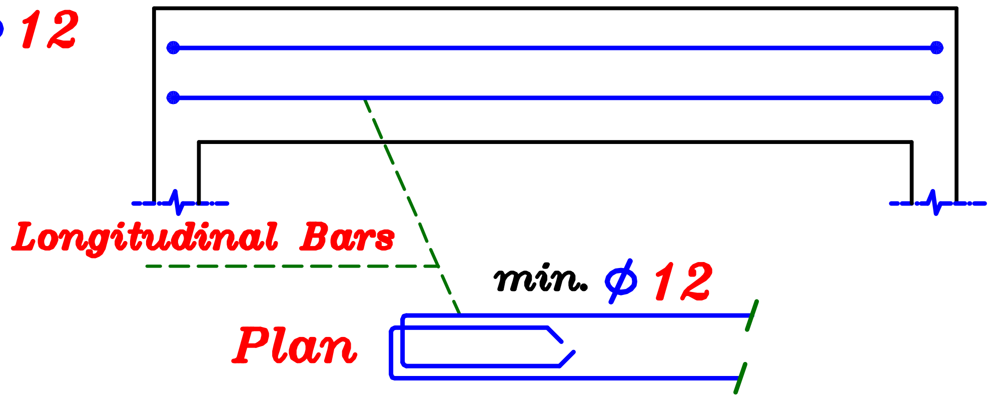
$$\boxed{A_{sl_{min}} = \frac{0.4\sqrt{\frac{F_{cu}}{\gamma_c}}}{\frac{F_y}{\gamma_s}} * A_c - \frac{A_{str} * P_h}{S_t}\left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right)}$$

A_c هى المساحه الكليه للقطاع بما فيها الفتحات .



- توزع الأسياخ على محيط القطاع بانتظام .
- المسافه بين الأسياخ لا تزيد عن ٣٠٠ مم .
- أقل قطر للسيخ ϕ 12





اذاً لرص تسليح الـ *Longitudinal Bars*

يتم زياده مساحه $\frac{A_{sl}}{4}$ على مساحه التسليح الرئيسى للعزوم
ثم نحدد بعدها عدد الاسياخ الكليه و اقطارها .

يتم زياده مساحه $\frac{A_{sl}}{4}$ على مساحه الـ *Stirrup Hangers*
ثم نحدد بعدها عدد الاسياخ الكليه و اقطارها .

يتم وضع اسياخ جانبيه بدل الـ *Shrinkage Bars*
قيمتها 1 ϕ 12 كل ٣٠٠ مم و توضع حتى لو كان $t < 700$ mm

Case ④ $q_u > q_{cu}$ & $q_{tu} > q_{tmin}$

Use Shear RFT. to resist Shear Stresses (q_{tu}) applied From Torsional moment.

+ Shear RFT. to resist Shear Stresses $\left(q_u - \frac{q_{cu}}{2}\right)$ applied From Shear Force.

① Closed Stirrups.

ⓐ Torsion.

$$\boxed{A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\left(\frac{F_y}{\gamma_s}\right)}} \longrightarrow A_{str} = \checkmark * S \quad \text{---} ①$$

كانات خارجيه فقط

A_{str} هى مساحه سيخ الكانه الخارجيه التى نحتاجها لمقاومه ال Torsion فقط.

ⓑ Shear.

$$\boxed{q_u - \frac{q_{cu}}{2} = \frac{n\ A_s\,(F_y \backslash \gamma_s)}{b\ \ S_s}} \longrightarrow A_s = \checkmark * \frac{S}{n} \quad \text{---} ②$$

كانات خارجيه و ممكن كانات داخليه

A_s هى مساحه مقطع سيخ واحد من الكانه الخارجيه أو الداخليه التى نحتاجها لمقاومه ال Shear فقط.

– نبدأ أولاً بفرض أن عدد فروع الكانه يساوى فرعين $n = 2$ و عدد الكانات

فى المتر = من (٥ ⟵ ١٠) أسياخ/م ثم نحسب $S = \frac{1000}{No\ of\ st.\backslash m}$ ثم نحسب A_{str} ، A_s

و تكون مساحه السيخ من الكانات الخارجيه $A_{s_{outer}} = A_{str} + A_s$

– فاذا كانت $113\ mm^2 \geq A_{s_{outer}}$ أى أن $\phi 12 \geq \phi_{Outer}$

فنختار $\phi_{Outer} = \phi 8$ or $\phi 10$ or $\phi 12$ و لا توجد كانات داخليه

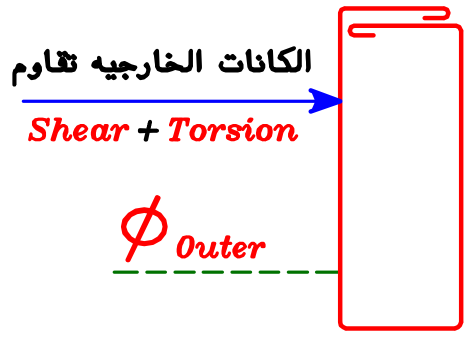
– أما اذا كانت $A_{s_{outer}} > 113\ mm^2$ فنختار عدد كانات أكثر فى المتر أو نأخذ $n = 4$

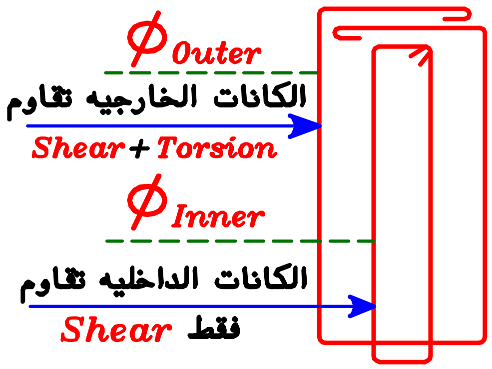
ثم تحديد قيمه A_s و تحديد قيمه $A_{s_{outer}} = A_{str} + A_s$

و تحديد قيمه $A_{s_{inner}} = A_s$

ترتيب اختيار الفروض لـ n , S

Assumption No.	n	No. of stirrups\m	$S_s = S_t$ (mm)
1	2	5.0	$\frac{1000}{5.0}$
2	2	6.0	$\frac{1000}{6.0}$
3	2	7.0	$\frac{1000}{7.0}$
4	2	8.0	$\frac{1000}{8.0}$
5	2	9.0	$\frac{1000}{9.0}$
6	2	10	$\frac{1000}{10}$
7	4	5.0	$\frac{1000}{5.0}$
8	4	6.0	$\frac{1000}{6.0}$
9	4	7.0	$\frac{1000}{7.0}$
10	4	8.0	$\frac{1000}{8.0}$
11	4	9.0	$\frac{1000}{9.0}$
12	4	10	$\frac{1000}{10}$





min. Stirrups.

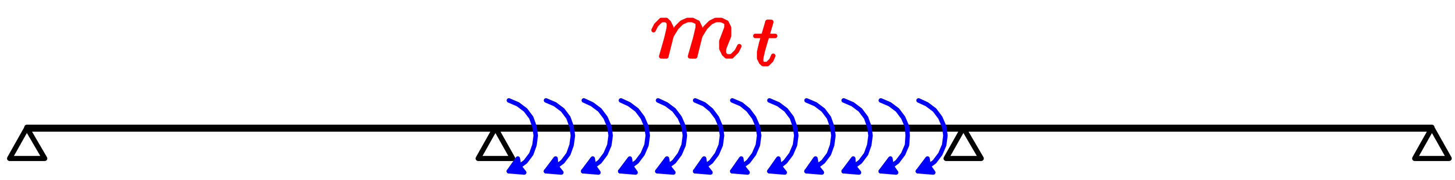
$$\boxed{\frac{2A_{str} + n\,A_s}{b * S} \not< \frac{0.4}{F_y}}$$

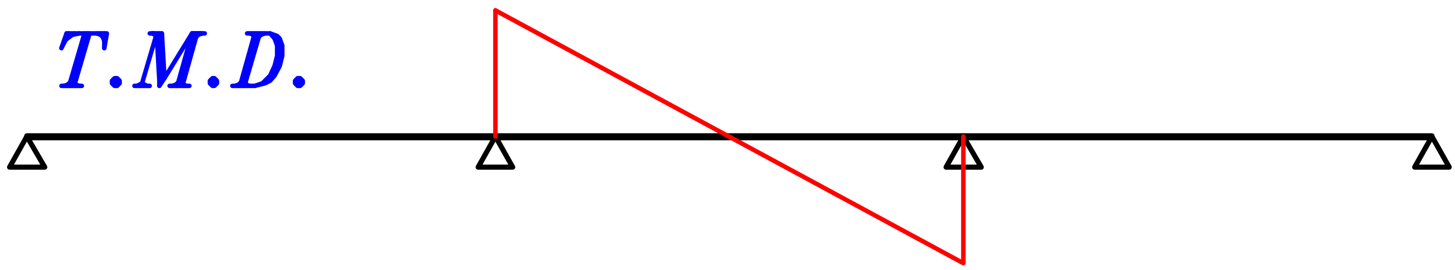
② Longitudinal Bars. Torsion only

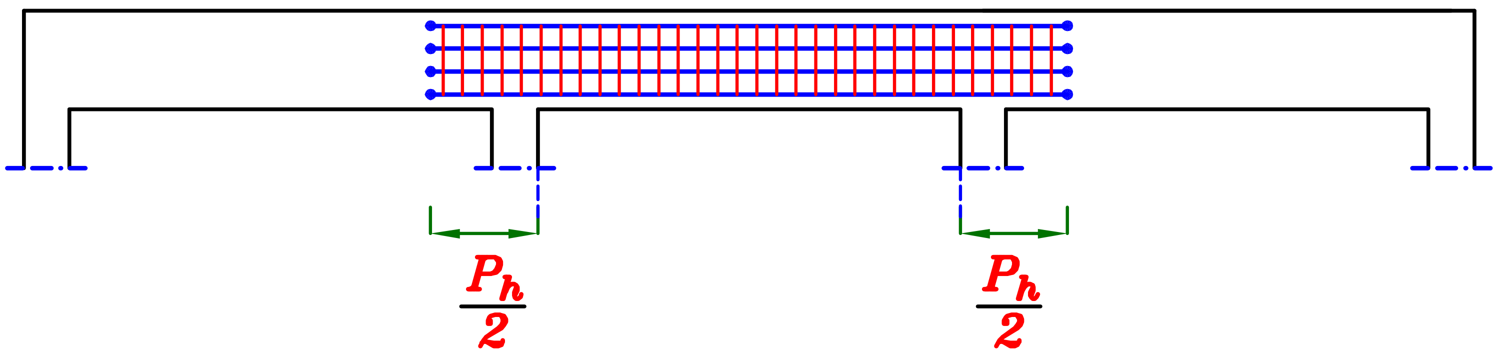
$$\boxed{A_{sl} = \frac{A_{str} * P_h}{S_t}\left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right)}$$

ملحوظه .

يجب ان تمتد كانات الـ **Torsion** و اسياخ الـ **Longitudinal Bars** مسافه لا تقل عن $\frac{P_h}{2}$ بعد اخر قطاع عليه **Torsional moment**

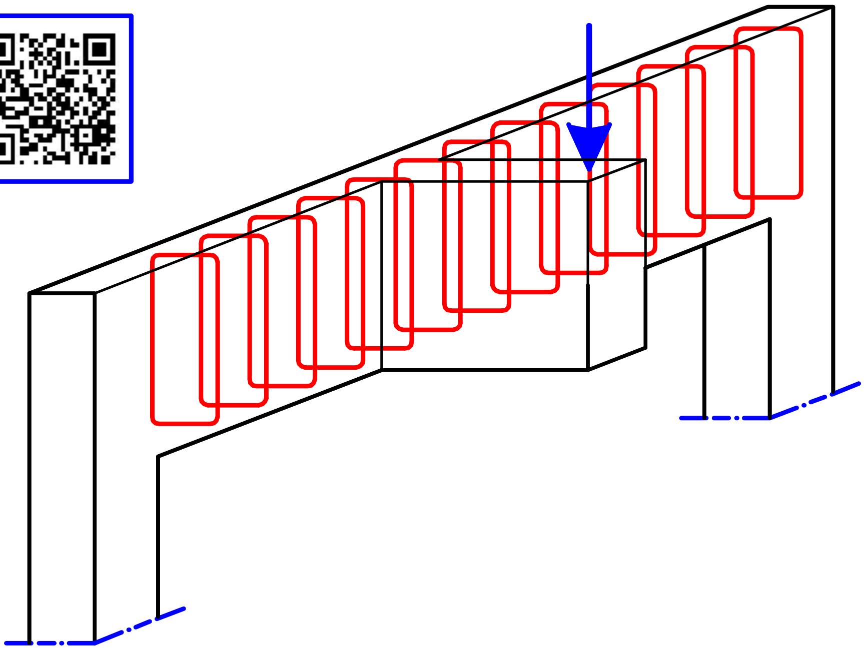
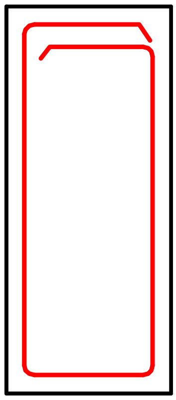




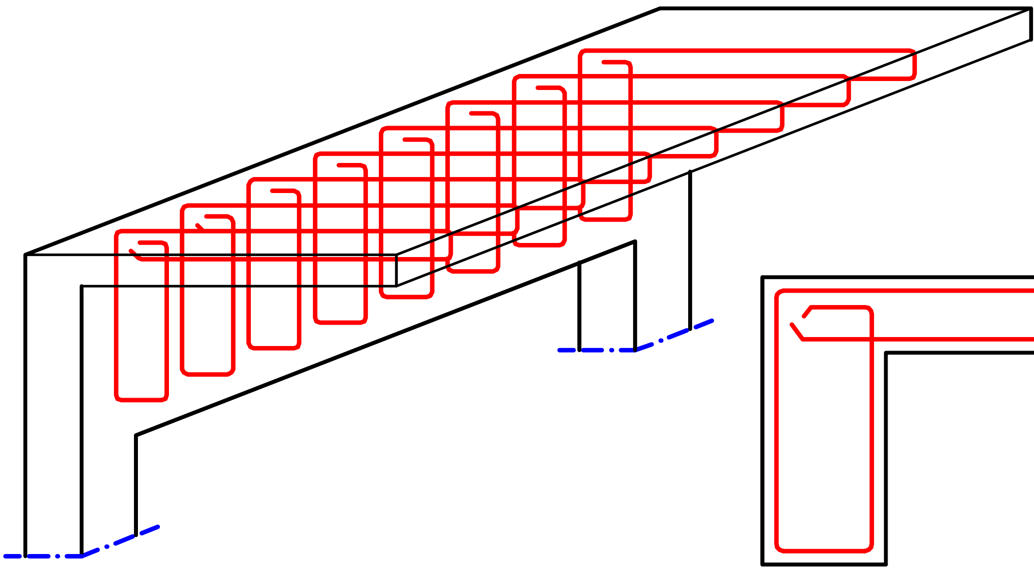


توجد حالتان لكانات الـ torsion :

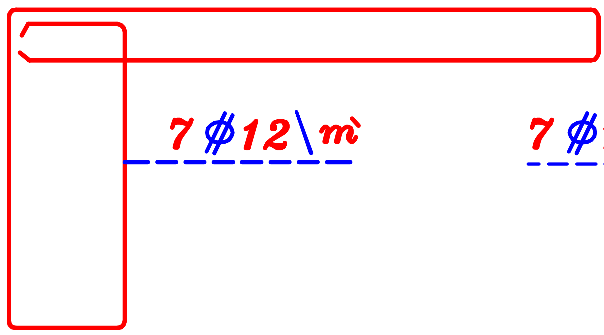
١- اذا لم يوجد تسليح للبلاطه يعمل كانات الكمره
فى هذه الحاله سيتم تصميم كانات لمقاومه الـ torsion

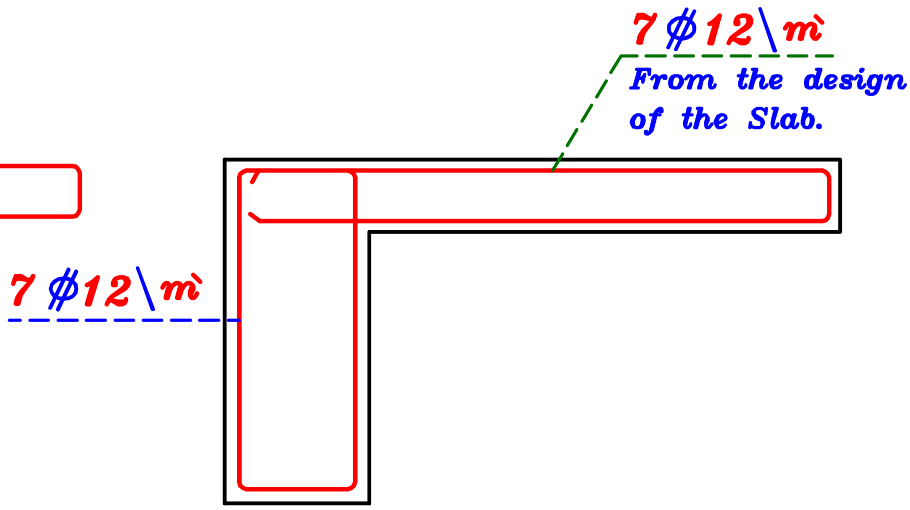



٢- اذا كان تسليح البلاطه يعمل ككانات للكمره .
فى هذه الحاله تعتبر كانات الكمره معطاه (و هى تسليح البلاطه).
لذا سنعمل Check اذا كانت كانات الكمره كافيه ام سنحتاج لزيادتها .




Notes.





إذا كان تسليح البلاطه $7\phi 12\backslash m$ ⟵ الكانات $7\phi 12\backslash m$

سنأخذ عدد الكانات الخارجيه = ٧ كانات فى المتر و فرعان للكانه

و $F_y = 360\ N\backslash mm^2$ و لا نأخذ كانات داخليه .

ثم نعمل Check إذا كانت $A_{s_{outer}} = \phi 12 = 113\ mm^2$

تكفى لتحمل الـ Shear Stress أم أننا سنحتاج إلى إستخدام كانات داخليه .

For Torsion Eqn.

$$A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\ \left(\frac{F_y}{\gamma_s}\right)} \longrightarrow A_{str} = \checkmark$$

$$S_t = \frac{1000}{7.0}\ ,\quad F_y = 360\ N\backslash mm^2$$

For Shear Eqn.

$$q_u - \frac{q_{cu}}{2} = \frac{n\,A_s\,(F_y\backslash\gamma_s)}{b\ S_s} \longrightarrow A_s = \checkmark$$

$$n = 2\ ,\quad S_s = \frac{1000}{7.0}\ ,\quad F_y = 360\ N\backslash mm^2$$

After we get A_s , A_{str} chek $A_{s_{outer}} = A_{str} + A_s \leq 113\ mm^2$

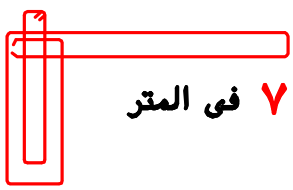
* IF $A_{s_{outer}} \leq 113\ mm^2 \therefore$ O.K.

تسليح البلاطه هو نفس تسليح الكانه الخارجيه

* IF $A_{s_{outer}} > 113\ mm^2$

$\therefore$ use another RFT. system

or use choose another ϕ_{Inner}



نختار كانات داخليه عددها ٧ فى المتر

Example.

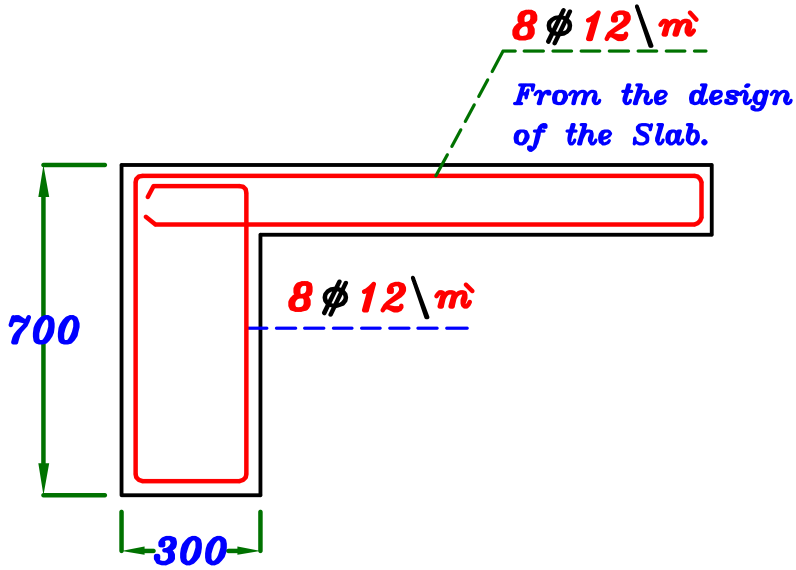
$F_{cu} = 25 \; N\backslash mm^2$

$F_y = 360 \; N\backslash mm^2$

$M_{tu} = 55.8 \; kN.m$

$q_u = 1.06 \; N\backslash mm^2$

$q_t = 2.38 \; N\backslash mm^2$



RFT. of the cantilever Slab 8 ϕ 12\m`

Req.

Check the Stirrups For Shear & Torsion.

Solution.

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98 \; N/mm^2 \; , \; q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245 \; N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85 \; N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{1.06^2 + 2.38^2} = 2.60 < q_{u\,max} \therefore o.k.$$

$q_u > q_{cu} \; , \; q_{tu} > q_{t\,min}$	resist $\left(q_u - \frac{q_{cu}}{2}\right) + (q_{tu})$

@ Torsion.

$x_1 = 220 \; mm \; , \; y_1 = 620 \; mm \; , \; A_{oh} = 220 * 620 = 136400 \; mm^2$

$$A_{str} = \frac{M_{tu} \; S_t}{(1.7) \; A_{oh} \; \left(\frac{F_y}{\gamma_s}\right)} \quad \therefore A_{str} = \frac{(55.8 * 10^6) \; S_t}{(1.7)(136400)(360/1.15)}$$

$$\therefore \boxed{A_{str} = 0.768 \; S_t}$$

ⓑ Shear.

$$q_u - \frac{q_{cu}}{2} = \frac{n\,A_s\,(F_y \backslash \gamma_s)}{b\;S_s} \qquad \therefore\; 1.06 - \frac{0.98}{2} = \frac{n\,A_s\;(360/1.15)}{(300)\;S_s}$$

$$\therefore\; \boxed{A_s = 0.546\;\frac{S_s}{n}}$$

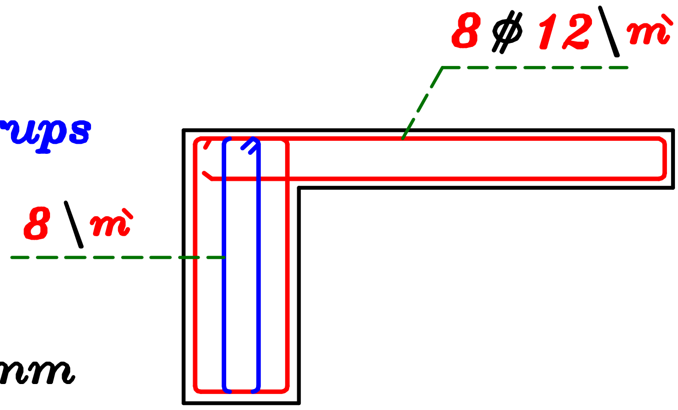
$$n = 2\;,\; S_t = S_s = \frac{1000}{8.0} = 125\ mm$$

$$\therefore\; A_{str} = 0.768\;S_t = 0.768 * 125 = 96.0\ mm^2$$

$$A_s = 0.546\;\frac{S_s}{n} = 0.546 * \frac{125}{2.0} = 34.12\ mm^2$$

$$A_{s\,outer} = A_{str} + A_s = 96.0 + 34.12 = 130.12 > 113$$

$\therefore$ *We have to use Inner Stirrups*



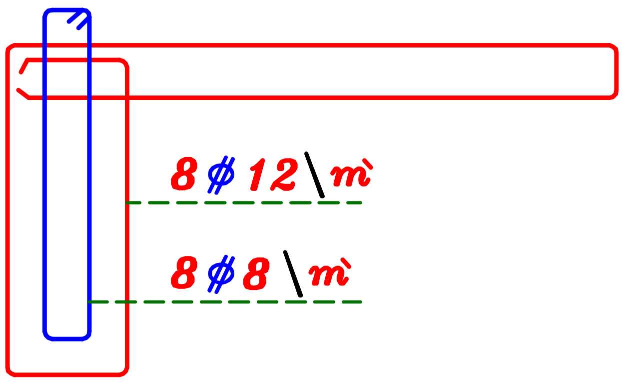
$$n = 4\;,\; S_t = S_s = \frac{1000}{8.0} = 125\ mm$$

$$\therefore\; A_{str} = 0.768\;S_t = 0.768 * 125 = 96.0\ mm^2$$

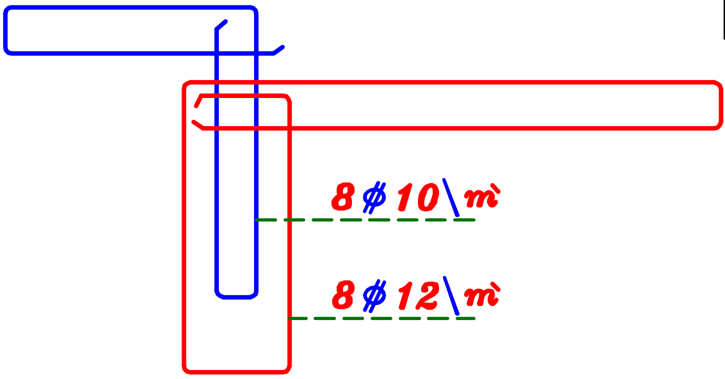
$$A_s = 0.546\;\frac{S_s}{n} = 0.546 * \frac{125}{4.0} = 17.0\ mm^2$$

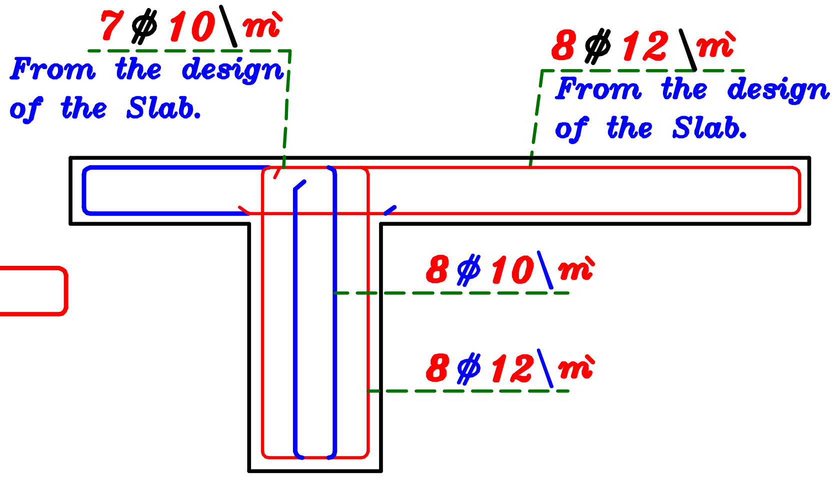
$$A_{s\,outer} = A_{str} + A_s = 96.0 + 17.0 = 113 \leqslant 113 \quad \therefore\ O.K.$$

$$A_{s\,inner} = A_s = 17.0\ mm^2 = \phi 8$$



Example.





إذا كان تسليح الكابولى الأكبر $8\phi 12\backslash m'$

سنأخذ الكانات الخارجيه $8\phi 12\backslash m'$ $\quad F_y = 360\ N\backslash mm^2$

إذا كان تسليح الكابولى الأصغر $7\phi 10\backslash m'$ سوف نأخذه $8\phi 10\backslash m'$ و نأخذ

الكانات الداخليه $8\phi 10\backslash m'$ لكى يكون عدد الكانات الداخليه و الخارجيه متساوى

ثم نعمل Check إذا كانت $A_{s\,outer} \leqslant \phi 12 = 113\ mm^2$ و $A_{s\,inner} \leqslant \phi 10 = 78.5\ mm^2$

تكفى لتحمل ال Shear Stress

For Torsion Eqn.

$$F_y = 360\ N\backslash mm^2 \quad , \quad S_t = \frac{1000}{8.0}$$

$$A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\ \left(\frac{F_y}{\gamma_s}\right)} \longrightarrow \boxed{A_{str} = \checkmark}$$

For Shear Eqn.

$$n = 4 \quad , \quad F_y = 360\ N\backslash mm^2 \quad , \quad S_s = \frac{1000}{8.0}$$

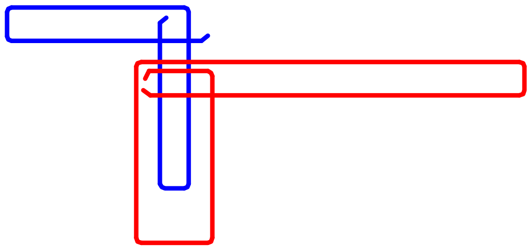
$$q_u - \frac{q_{cu}}{2} = \frac{n\, A_s\,(F_y\backslash \gamma_s)}{b\ S_s} \longrightarrow \boxed{A_s = \checkmark}$$

After we get A_s, A_{str}

Get $A_{s_{outer}} = A_{str} + A_s \leqslant 113 \; mm^2$

$A_{s_{inner}} = A_s \leqslant 78.5 \; mm^2$

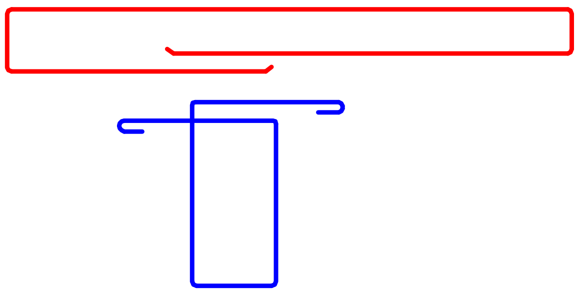
Check.



* IF $A_{s_{outer}} \leqslant 113 \; mm^2$

$A_{s_{inner}} \leqslant 78.5 \; mm^2$

$\therefore$ O.K. تسليح البلاطه هو نفس تسليح الكانه الخارجيه



* IF $A_{s_{outer}} > 113 \; mm^2$

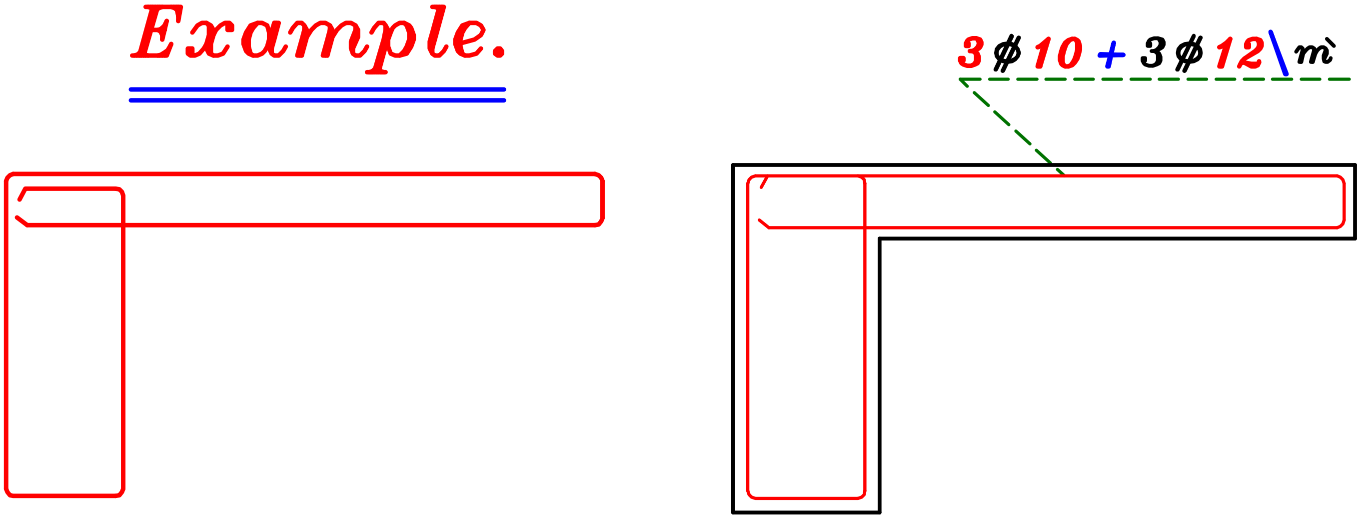
or $A_{s_{inner}} > 78.5 \; mm^2$

Increase Dimensions

or use another RFT. system

ليس شرط أن يكون تسليح البلاطه
هو نفس تسليح الكانه الخارجيه

Example.

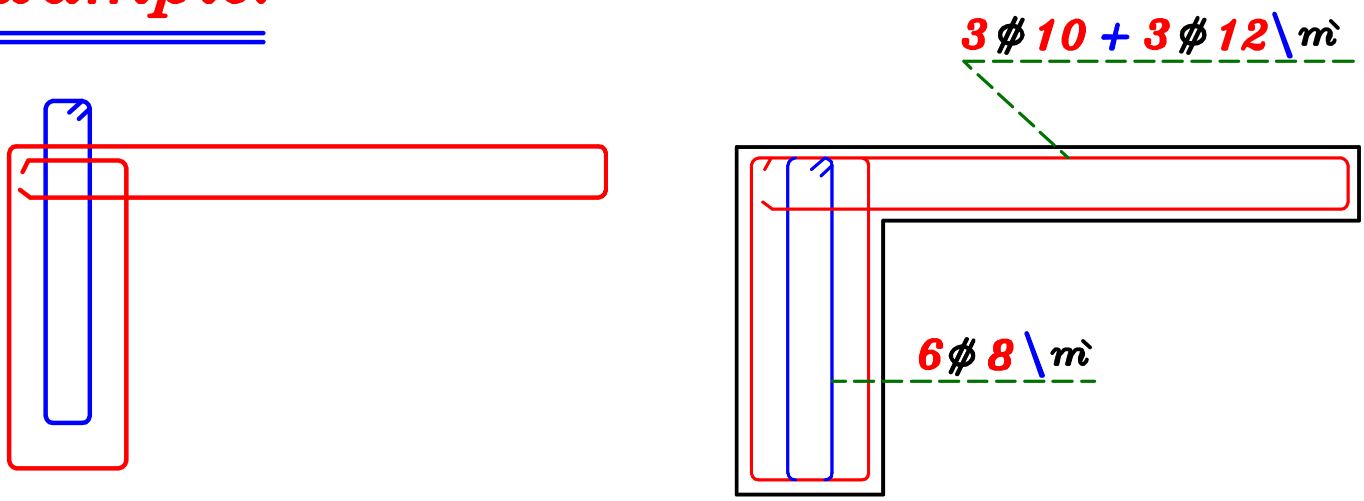


For Shear Eqn. $n = 2$, $S_s = \frac{1000}{6.0}$, $F_y = 360$ N\mm^2

For Torsion Eqn. $S_t = \frac{1000}{6.0}$, $F_y = 360$ N\mm^2

, Check $A_{s_{outer}} = A_s + A_{str} \leqslant \left(\frac{78.5 + 113}{2}\right)$

Example.



For Shear Eqn. $n = 4$, $S_s = \frac{1000}{6.0}$, $F_y = 360$ N\mm^2

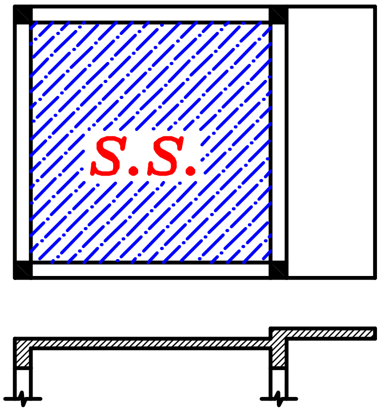
For Torsion Eqn. $S_t = \frac{1000}{6.0}$, $F_y = 360$ N\mm^2

Check $A_{s_{inner}} = A_s \leqslant 50.3$

, Check $A_{s_{outer}} = A_s + A_{str} \leqslant \left(\frac{78.5 + 113}{2}\right)$

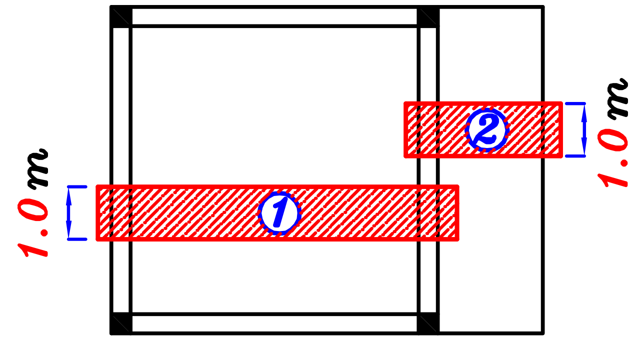
Special Cases.

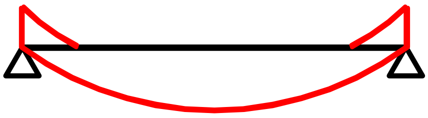
إذا وجد كابولى بجوار بلاطه الحمام



يوجد طريقتين للتسليح :

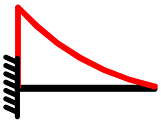
① نأخذ كل شريحه بمفردها

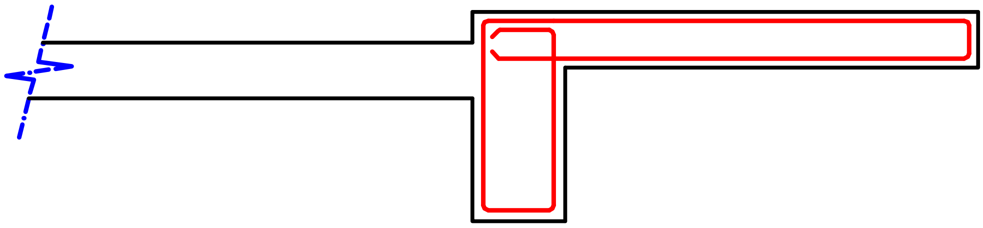


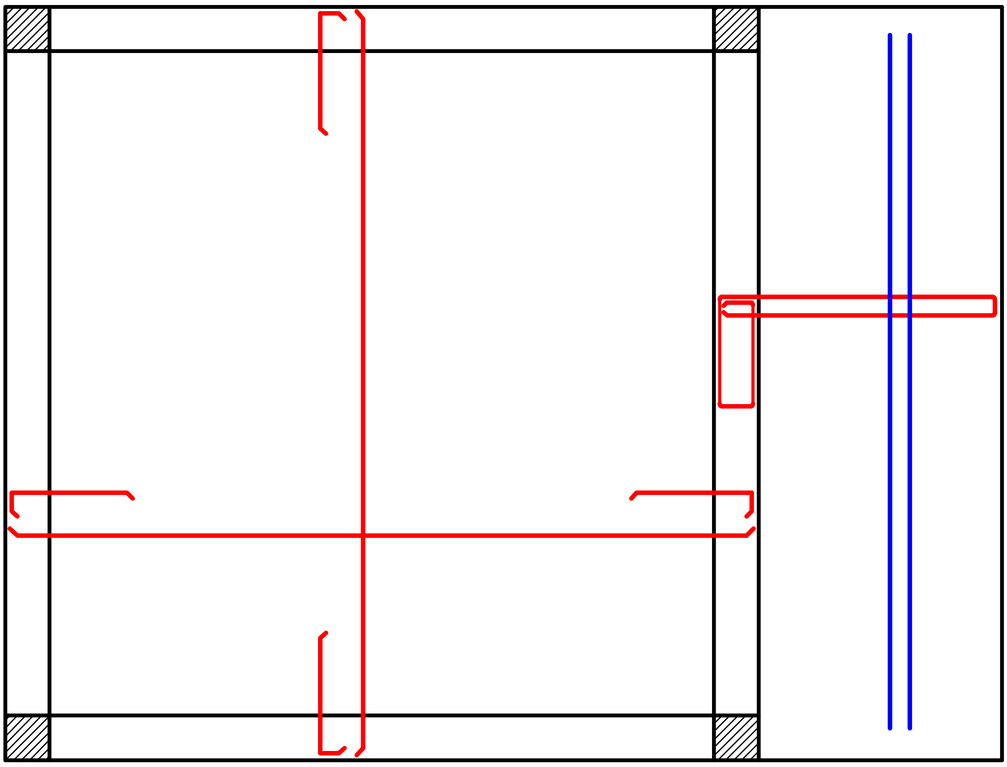


Strip ①

Strip ②

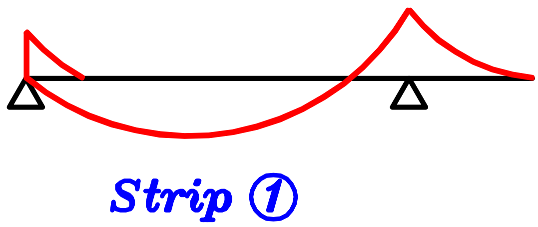


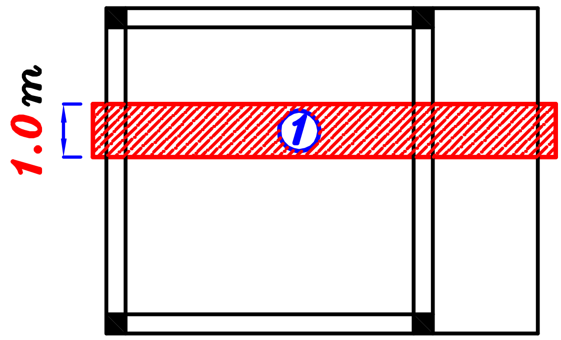


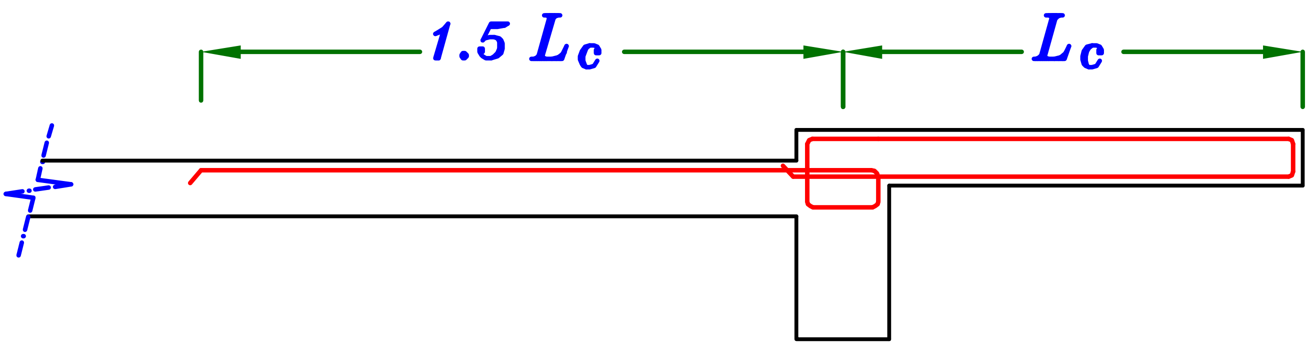


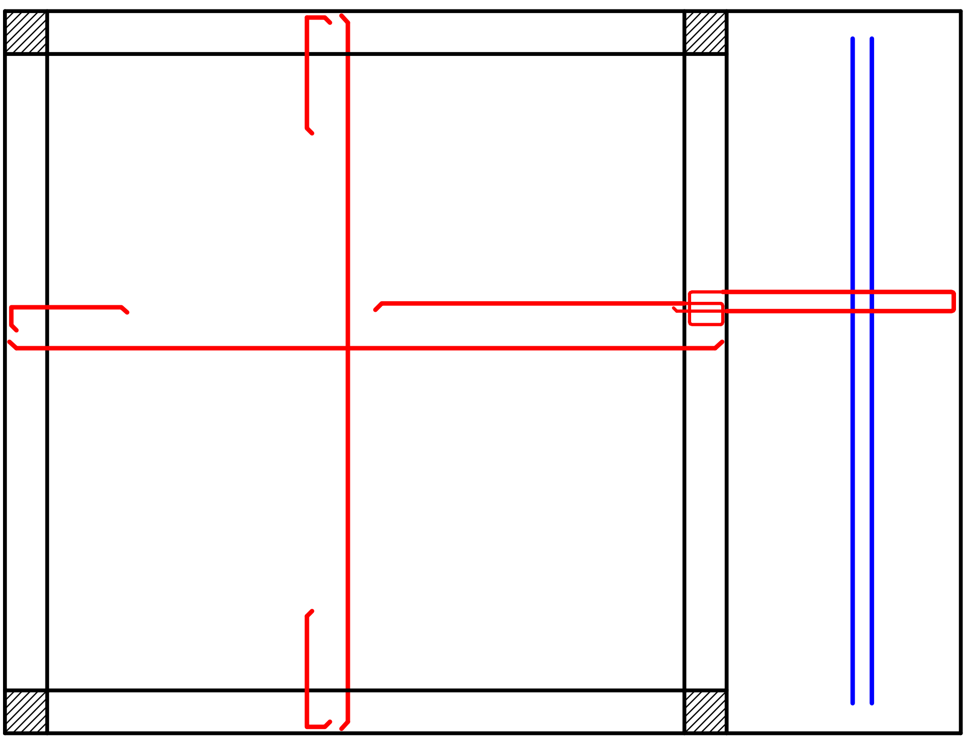
② نأخذ شريحه على البلاطه و الكابولى معا

فتكون محمولة على أكثر من *one support* فلا يتكون *Torsion* على الكمره

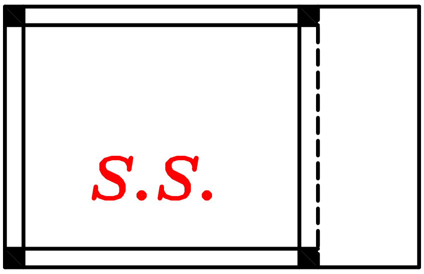








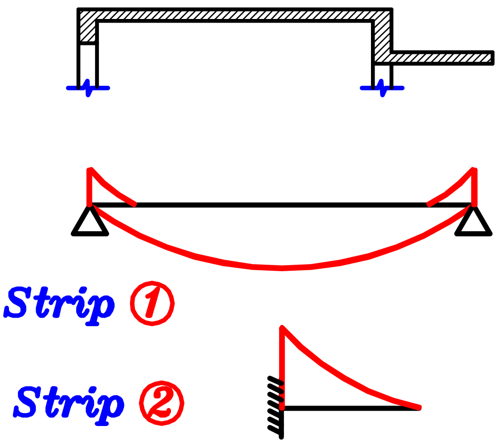
Special Case.

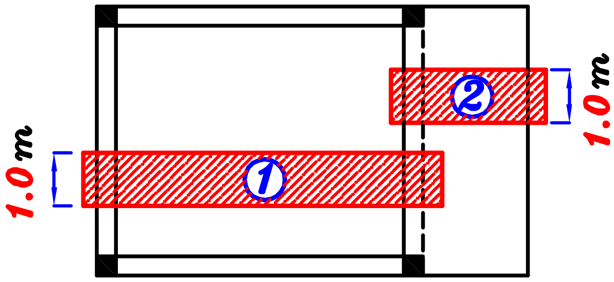


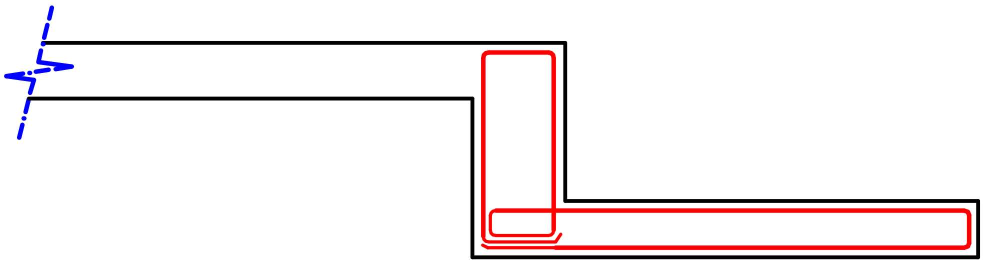
إذا وجد كابولى سفلى كما بالشكل

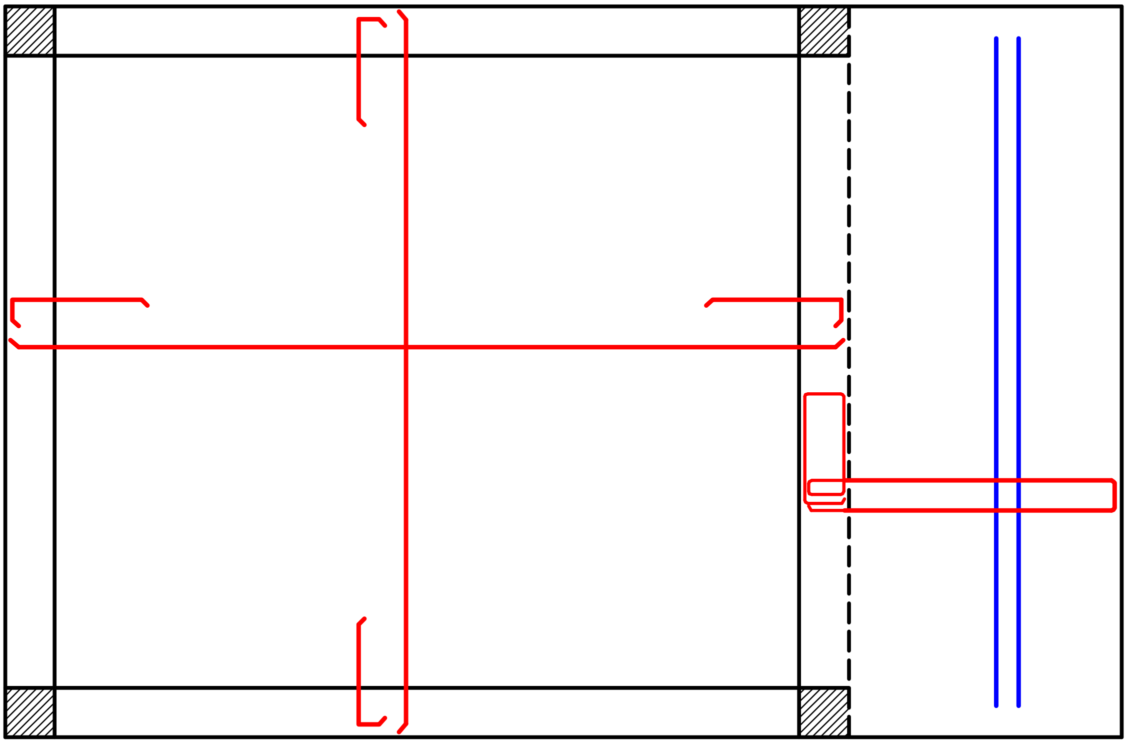
يوجد طريقتين للتسليح :

① نأخذ كل شريحه بمفردها



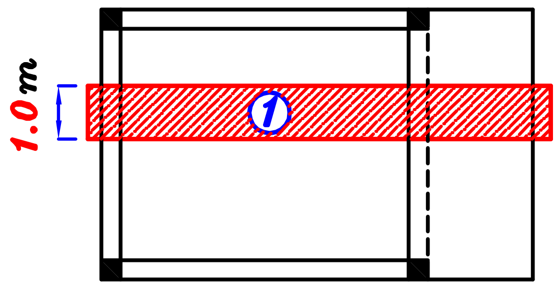


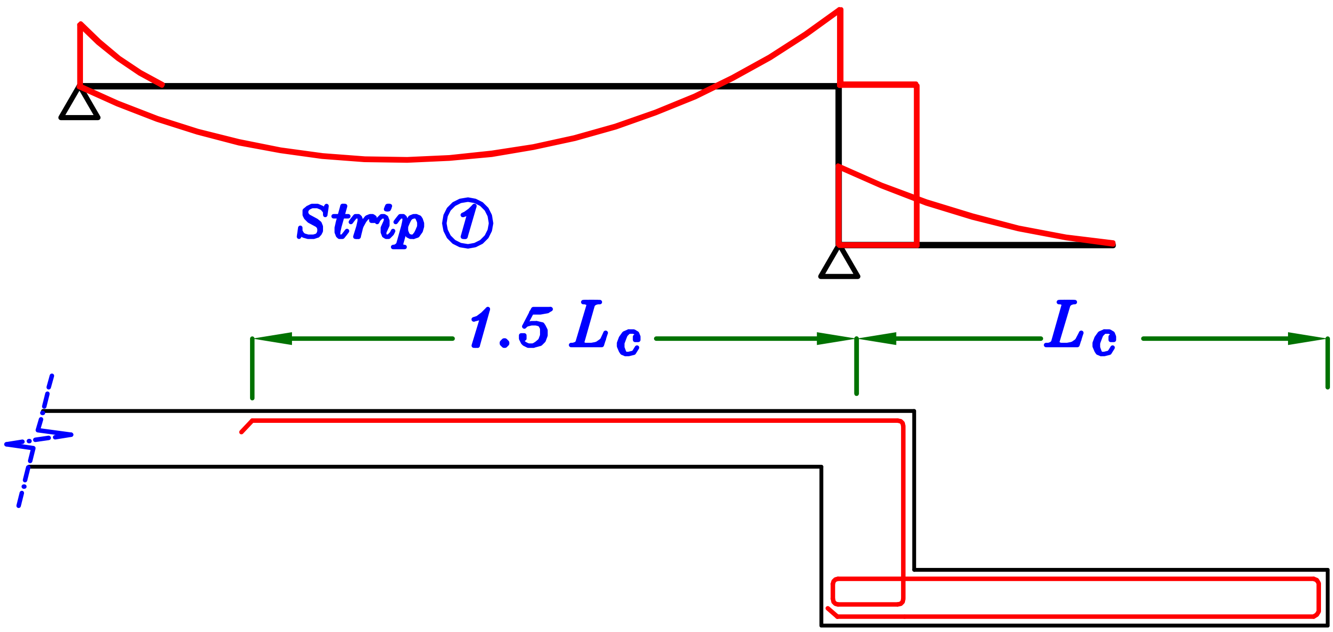


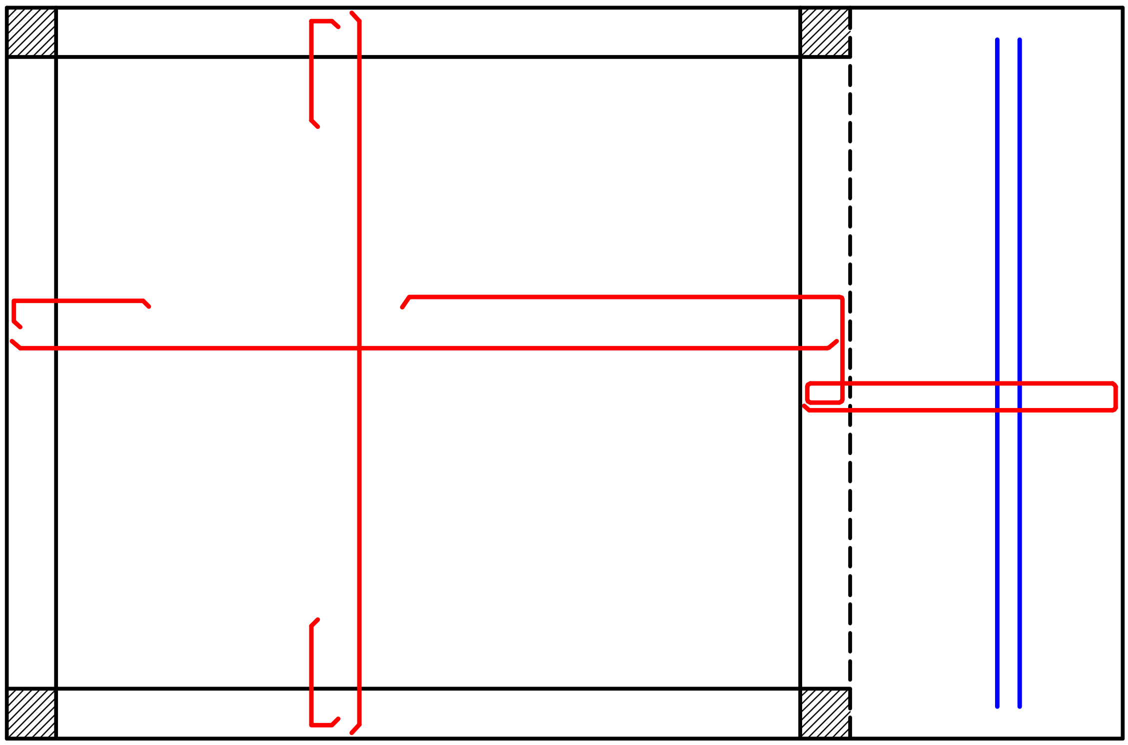


② نأخذ شريحه على البلاطه و الكابولى معا

فتكون محموله على أكثر من *one support* فلا يتكون *Torsion* على الكمره

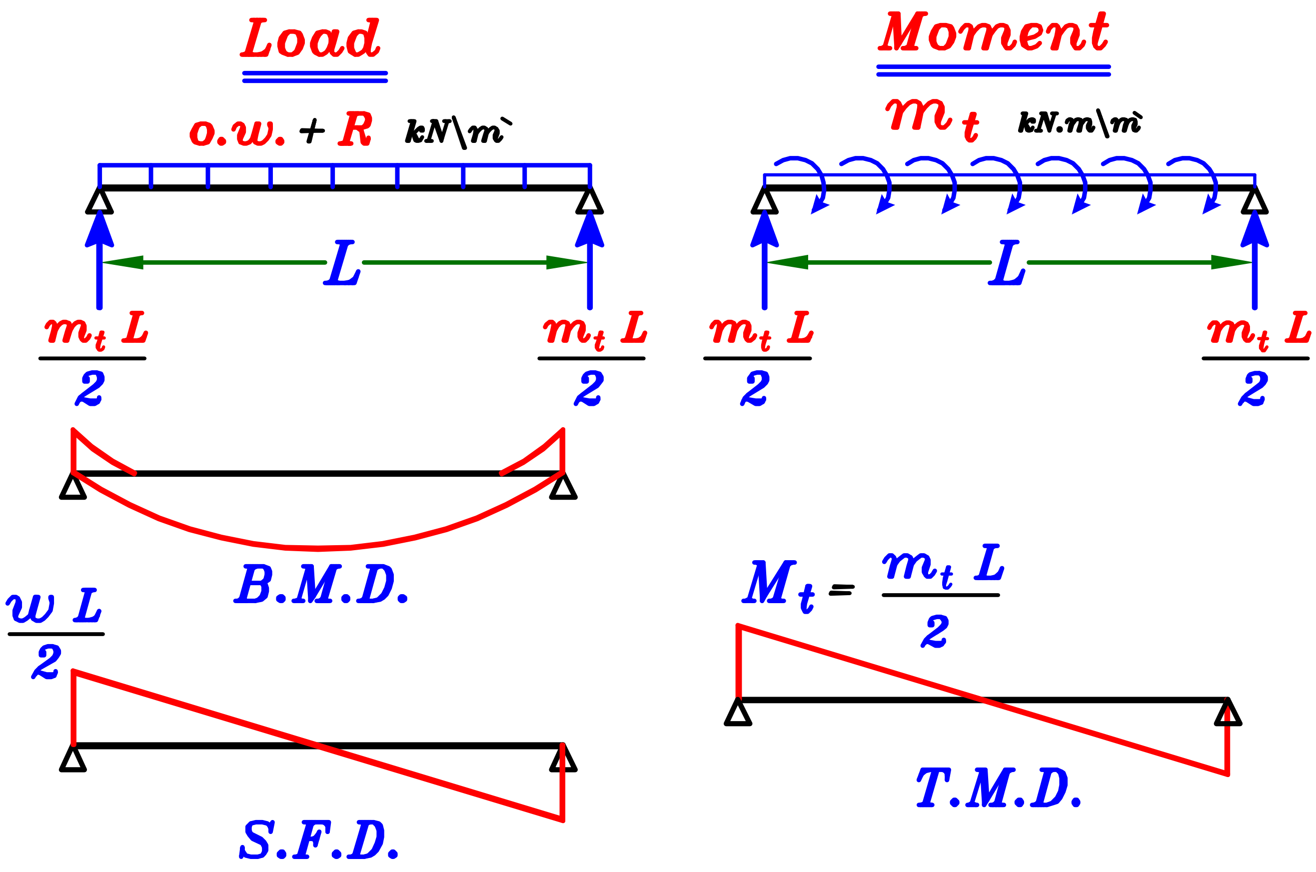






Steps of design a Beam
Subjected to Torsional Moment.

① Draw B.M.D. , S.F.D. & T.M.D.



② Estimate the Dimensions Of the Beam (b , t)

ⓐ $b =$ 300 mm OR 350 mm OR 400 mm

ⓑ Get t

$$\boxed{t_{tor.} \simeq \frac{3 M_t}{1.6 \ b^2}}$$

$$\boxed{t_{ben.} = 3.50 \sqrt{\frac{M}{F_{cu} \ b}}}$$

Take t = The bigger value of $t_{tor.}$, $t_{ben.}$

③ Design the beam according to B.M.

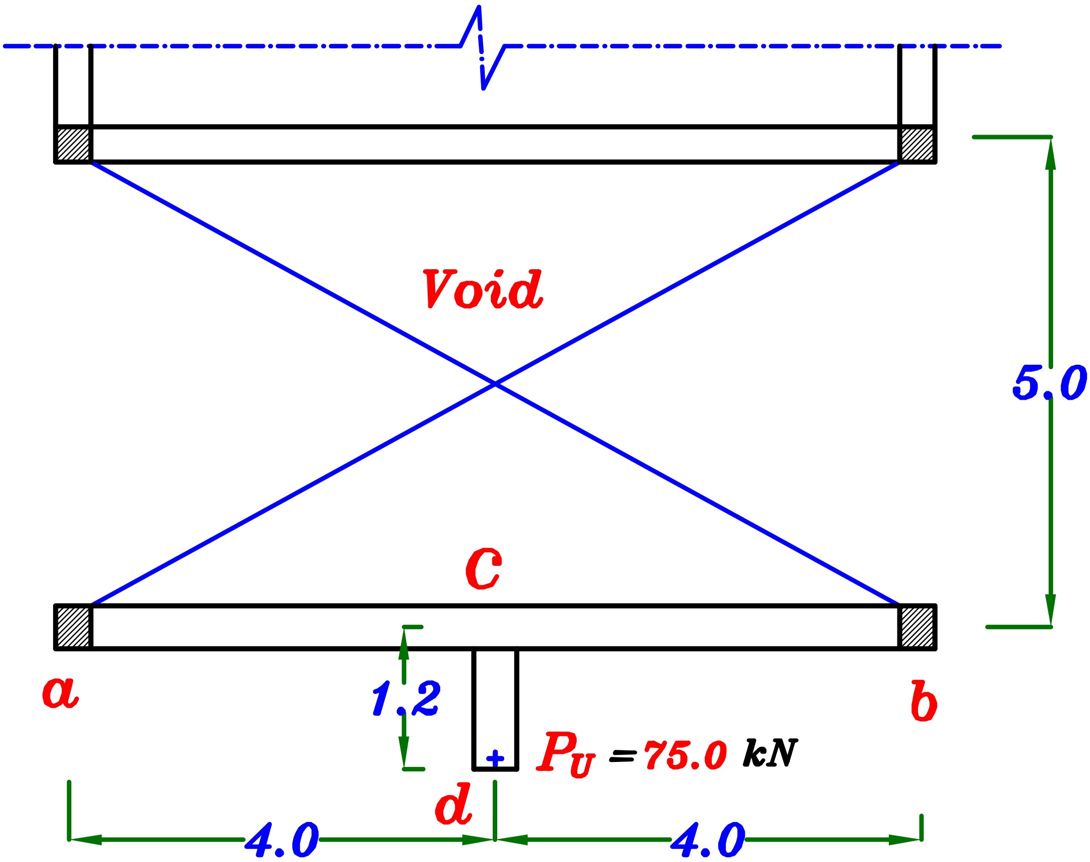
and get the main steel (A_s)

④ Design the beam according to Shear & Torsion.

and get Stirrups & Longitudinal Bars.

Examples on Torsion.

Example.



Data.

$F_{cu} = 25$ N\mm^2 $\quad F_y = 360$ N\mm^2

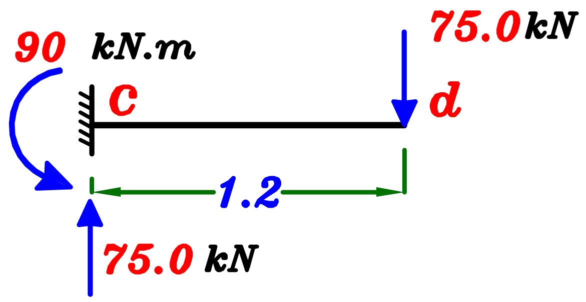
Req.

1. Design the beam (a b) and Cantilever (c d) (Neglecting the O.W.) and draw The details of RFT.
2. Get Loads on Column (b) at this case. and Draw the Internal Forces Diagrams For that Column.
3. Draw a necessary member to make beam (a b) Free of Torsion. and Draw the Internal Forces Diagrams For the Beam at this case.

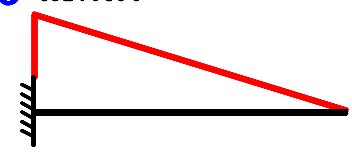
Solution.

①

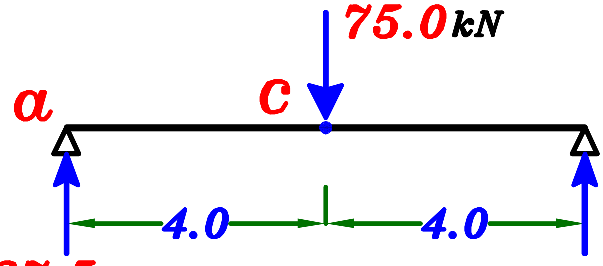
Loads on
The Cantilever (c d)



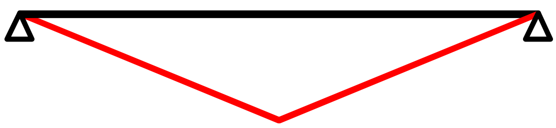
B.M.D. (c d)



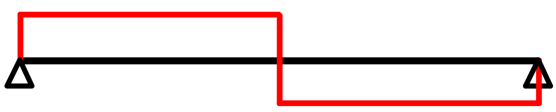
Loads on
The Beam (a b)



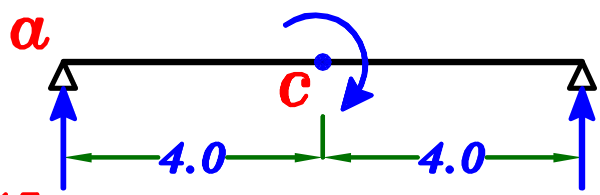
B.M.D. (a b)



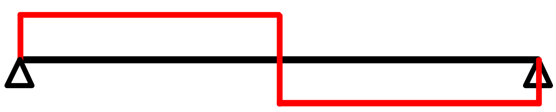
S.F.D. (a b)



Torsional Moment on
The Beam (a b)



T.M.D. (a b)



① Design of Cantilever (c d)

Sec. ①

$M_{U.L.} = 90.0$ kN.m R–Sec. Take $b = 250$ mm

– Take $C_1 = 3.50 \longrightarrow J = 0.78$

– Get $d = C_1 \sqrt{\dfrac{M_{U.L.}}{F_{cu}\, b}} = 3.50 \sqrt{\dfrac{90.0 * 10^6}{25 * 250}} = 420$ mm

– Take $\boxed{d = 450 \text{ mm}}$, $\boxed{t = 500 \text{ mm}}$

– Get $A_s = \dfrac{M_{U.L.}}{J\, F\, d} = \dfrac{90.0 * 10^6}{0.780 * 360 * 420} = 763 \text{ mm}^2$

Check $A_{s_{min.}}$ $A_{s_{req.}} = 763 \text{ mm}^2$

$\mu_{min.}\, b\, d = \left(0.225 * \dfrac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \dfrac{\sqrt{25}}{360}\right) 250 * 450 = 351.5 \text{ mm}^2$

$\therefore A_{s_{req.}} > \mu_{min.}\, b\, d \quad \therefore$ Take $A_s = A_{s_{req.}} = 763 \text{ mm}^2$ $4\phi16$

Dimensions of Beam (a b)

Take $b = 300$ mm

* $t_{ben.} = 3.50 \sqrt{\dfrac{M}{F_{cu}\, b}} = 3.50 \sqrt{\dfrac{150 * 10^6}{25 * 300}} = 494.9$ mm

* $t_{tor.} \simeq \dfrac{3\, M_t}{1.6 * b^2} = \dfrac{3 * 45 * 10^6}{1.6 * 300^2} = 937.5$ mm

take $\boxed{t = 950 \text{ mm}}$

Design of Beam (ab) For Bending.

$M_{U.L.} = 150\ kN.m \quad (300 * 950)$

$\because d = C_1 \sqrt{\dfrac{M_{U.L.}}{F_{cu}\, B}} \quad \therefore 900 = C_1 \sqrt{\dfrac{150.0 * 10^6}{25 * 300}} \longrightarrow C_1 = 6.36 \longrightarrow J = 0.826$

$$\therefore A_s = \frac{M_{U.L.}}{J\, F_y\, d} = \frac{150.0 * 10^6}{0.826 * 360 * 900} = 560.4\ mm^2$$

Check $A_{s_{min.}}$ $\qquad A_{s\ req.} = 560.4\ mm^2$

$$\mu_{min.}\, b\, d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 900 = 843.7\ mm^2$$

$\therefore \mu_{min.}\, b\, d > A_{s_{req.}} \xrightarrow{Use} A_{s_{min.}}$

$A_{s_{min.}} = 0.225 * \dfrac{\sqrt{F_{cu}}}{F_y}\, b\, d = \left(0.225 * \dfrac{\sqrt{25}}{360}\right) 300 * 900 = 843.7$ } الأقل $= 728.5$

$1.3\, A_{s_{req.}} = 1.3 * 560.4 = 728.5$

} الأكبر $= 728.5\ mm^2$

st. 360/520 $\quad \dfrac{0.15}{100}\, b\, d = \dfrac{0.15}{100} * 300 * 900 = 405\ mm^2$

Design the beam For Shear + Torsion.

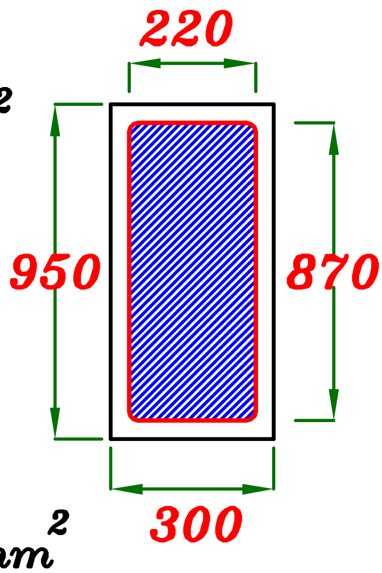
$$q_u = \frac{Q}{b\,d} = \frac{37.5 * 10^3}{300 * 900} = 0.138 \ N/mm^2$$

$$A_{oh} = 220 * 870 = 191400 \ mm^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 191400 = 162690 \ mm^2$$

$$P_h = 2 * 220 + 2 * 870 = 2180 \ mm$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{191400}{2180} = 87.80 \ mm$$



$$q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{45 * 10^6}{2 * 162690 * 87.80} = 1.575 \ N/mm^2$$

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98 \ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245 \ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85 \ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.138^2 + 1.575^2} = 1.581 \ N/mm^2 < q_{u\,max} \quad \therefore \text{o.k.}$$

$$\boxed{q_u < q_{cu} \ , \ q_{tu} > q_{t\,min}}$$ $\therefore$ Use RFT. For Torsion only.

* Stirrups.

$$\because A_{str} = \frac{M_{tu} \; S_t}{(1.7) \; A_{oh} \left(\frac{F_y}{\delta_s}\right)} \qquad \therefore A_{str} = \frac{(45 * 10^6) * S_t}{(1.7)(191400)(240/1.15)}$$

$$\therefore \boxed{S_t = 1.509 * A_{str}}$$

* Take $\phi\, 8 \longrightarrow A_{str} = 50.3 \; mm^2$

$\therefore S_t = 1.509 * A_{str} = 1.509 * 50.3 = 75.9 \; mm < 100 \; mm$

* Take $\phi\, 10 \longrightarrow A_{str} = 78.5 \; mm^2$

$\therefore S_t = 1.509 * A_{str} = 1.509 * 78.5 = 118.4 \; mm > 100 \; mm \; \therefore$ o.k.

$\therefore$ No. of stirrups\m` $= \frac{1000}{S} = \frac{1000}{118.4} = 8.44 = 9.0$

$\therefore$ Use Closed Stirrups $\boxed{9 \phi 10 \backslash m`}$ 2 branches.

---

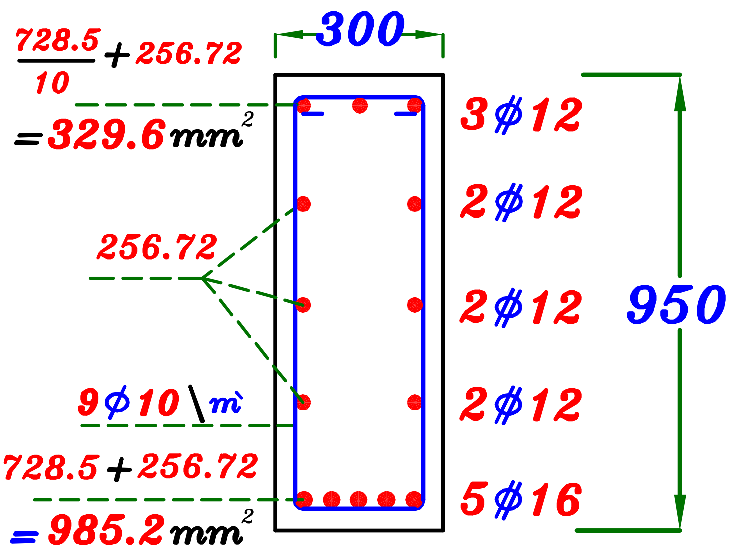
* Longitudinal Bars.

$$S_t = \frac{1000}{9} = 111.1 \; mm$$

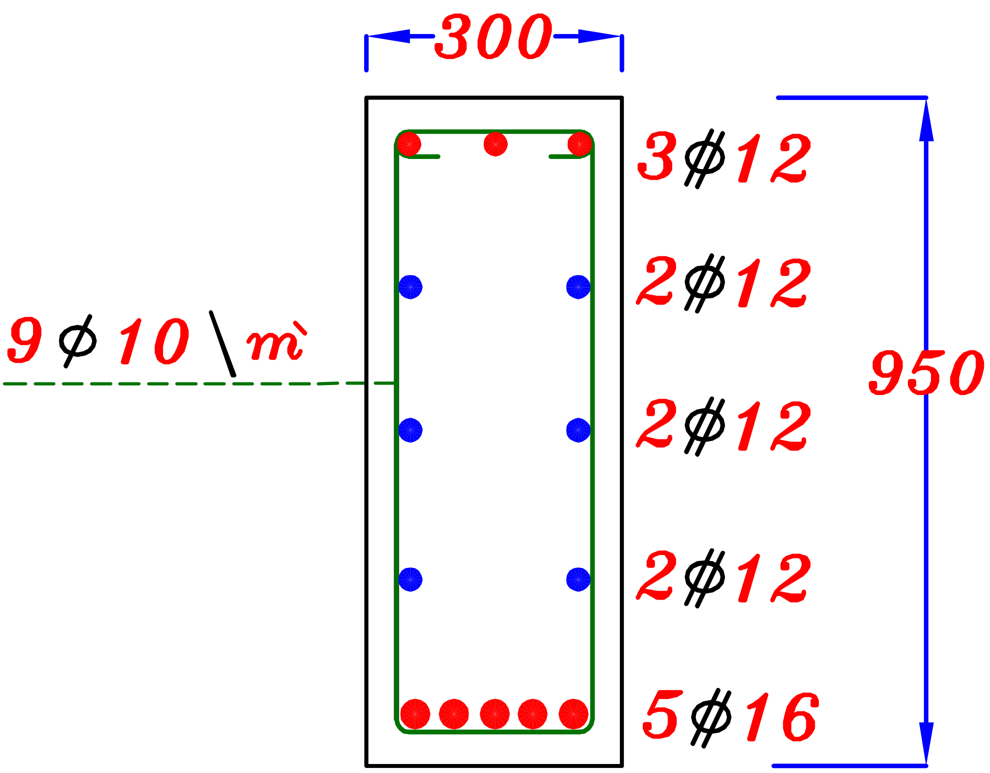
$$A_{sl} = \frac{A_{str} * P_h}{S_t} \left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right) = \frac{(78.5 * 2180)}{111.1} \left(\frac{240}{360}\right) = 1026.9 \; mm^2$$

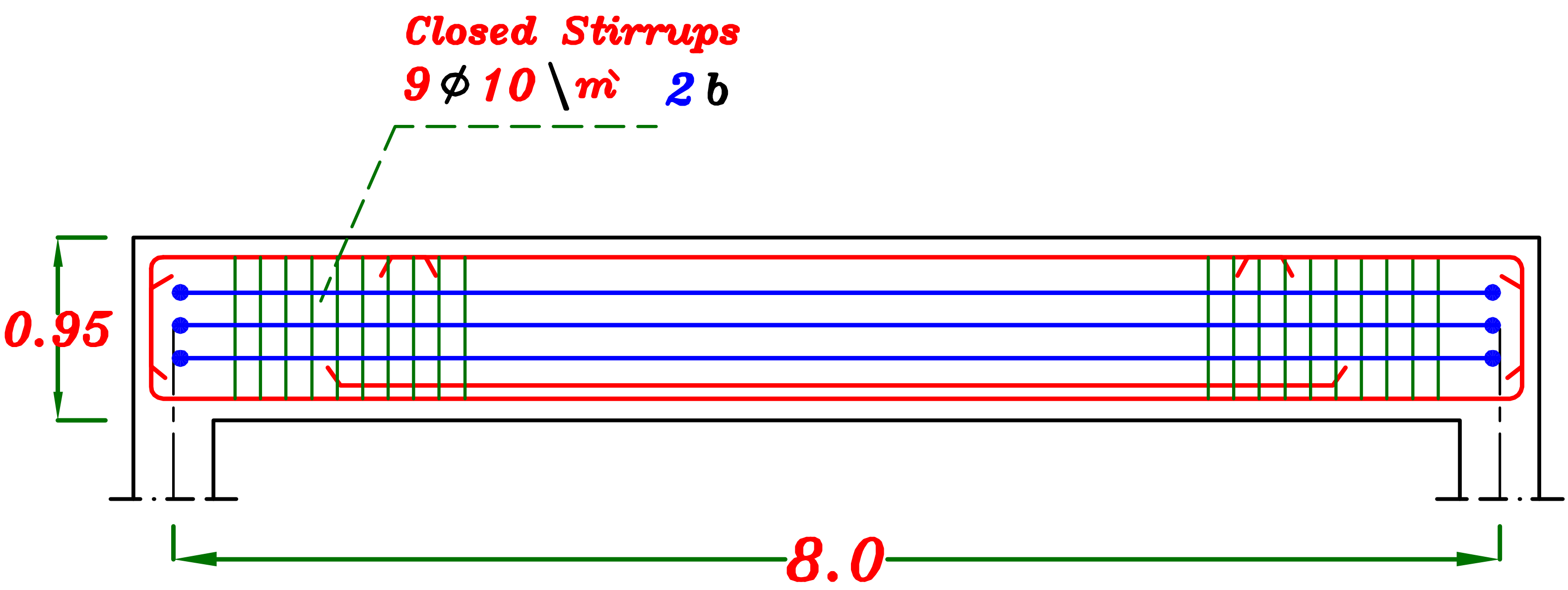
$$\therefore \frac{A_{sl}}{4} = \frac{1026.9}{4} = 256.72 \; mm^2$$

Cross Sec.
In Beam (a b)



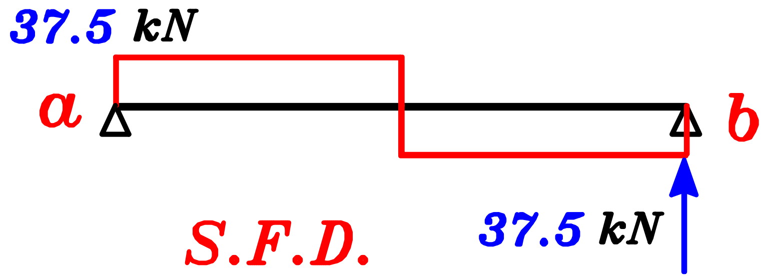
RFT. of Beam.


300
950
3φ12
2φ12
2φ12
2φ12
5φ16
9φ10\m`

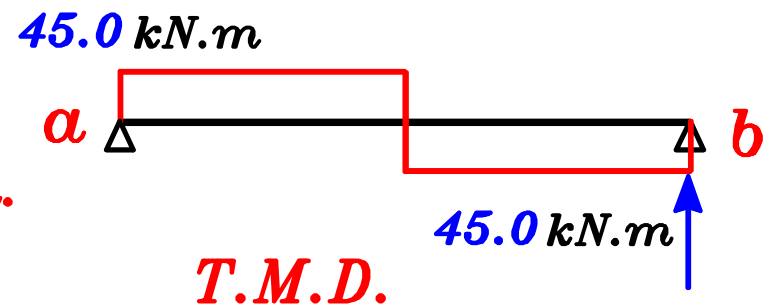

Closed Stirrups
9φ10\m` 2b
0.95
8.0

② Loads on Column (b)

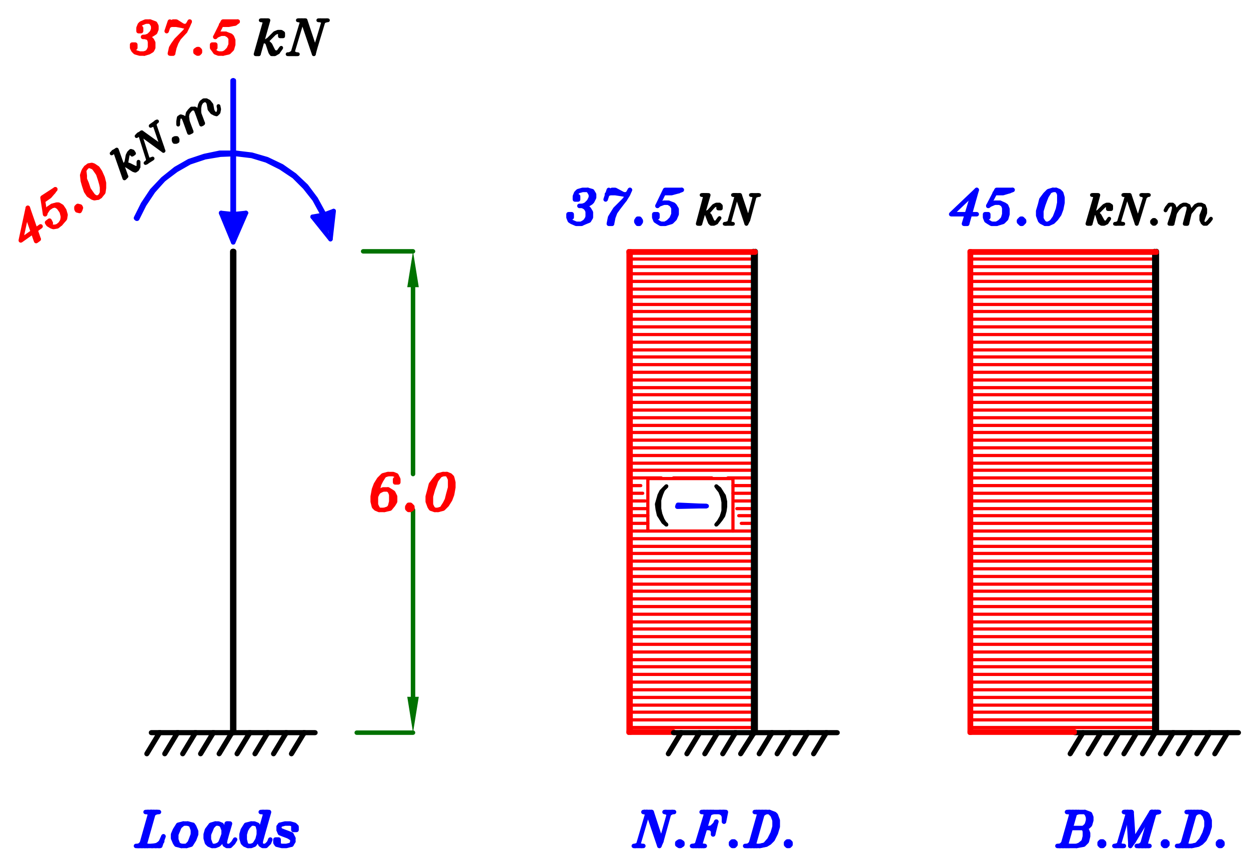
Reaction of S.F.D.
=
Load on the column.



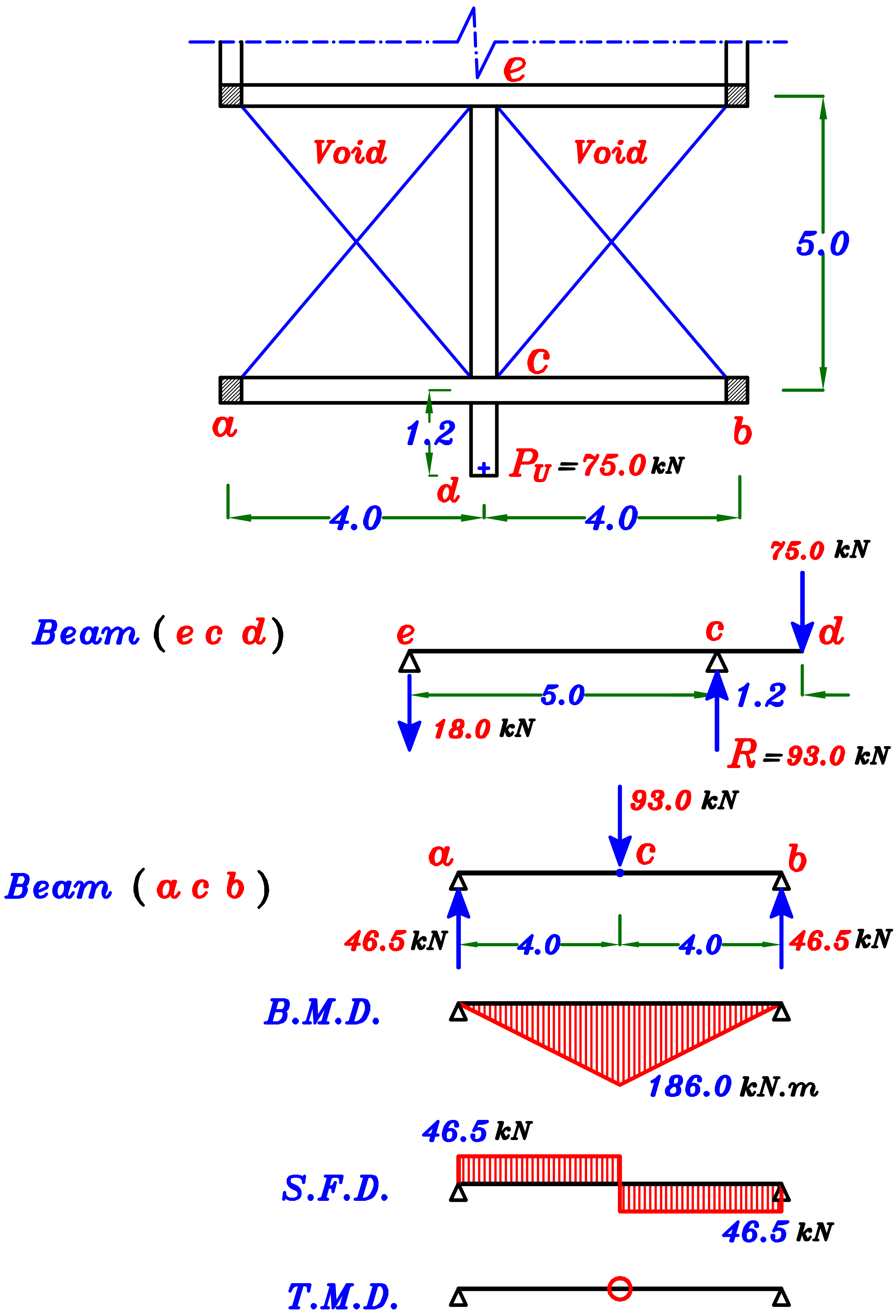
Reaction of T.M.D.
=
Bending on the column.



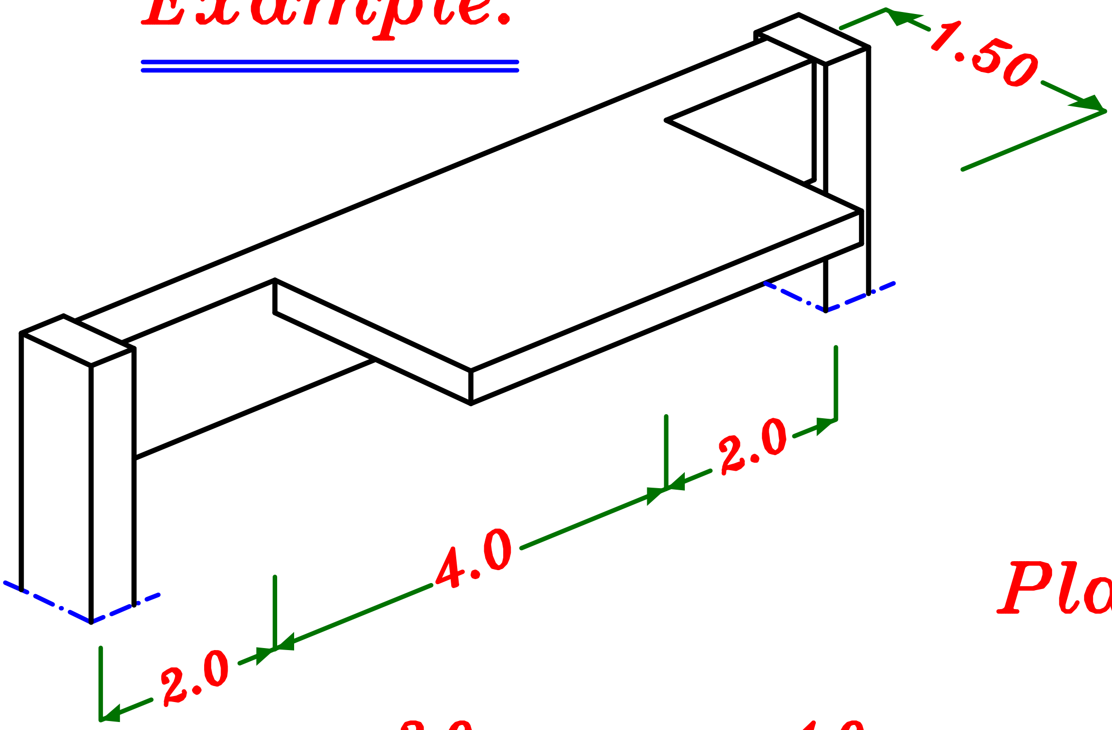
Internal Forces Diagrams on Column (b).



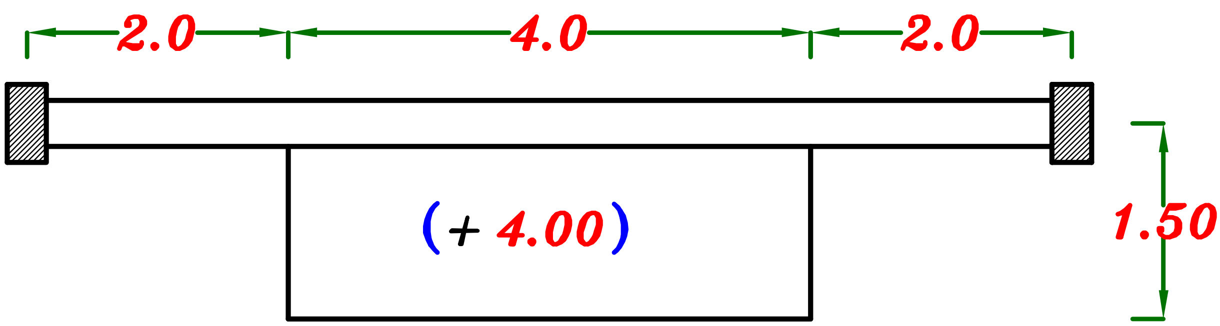
③ *To make the Beam (a b) Free of Torsion.*
We can put a member at (c e) as shown.



Example.



Plan



Data.

$F_{cu} = 25$ N\mm^2 , $F_y = 360$ N\mm^2

F.C. = 1.50 kN\m^2 , L.L. = 2.0 kN\m^2

Column (350 * 500)

Slab Level = (+ 4.00) m

Founation Level = (− 1.50) m

Req.

1. Complete design For The Slab , Beam & Column.
2. Draw the details of RFT. in plan , elevation & Cross sections.

Solution.

Loads on the Slab.

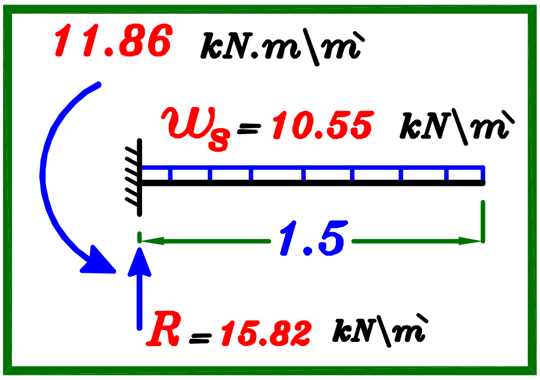
$$t_s = \frac{L_c}{10} = \frac{1500}{10} = 150\ mm$$

$$\boxed{t_s = 150\ mm}$$

$$w_s = 1.4\,(t_s\,\gamma_c + F.C.) + 1.6\,(L.L.)$$

$$w_s = 1.4\,(0.15 * 25 + 1.5) + 1.6\,(2.0) = 10.55\ kN\backslash m^2$$

Strip in the slab.

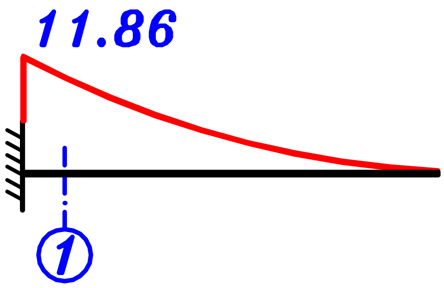


$$R = 10.55 * 1.5 = 15.82\ kN\backslash m`$$

$$M = \frac{10.55 * 1.5^2}{2} = 11.86\ kN.m\backslash m`$$

Design the Slab.

Sec. 1



$$M_{U.L.} = 11.86\ kN.m\backslash m$$

$$,\ t_s = 150\ mm\ ,\ d = 130\ mm$$

$$130 = C_1\sqrt{\frac{11.86 * 10^6}{25 * 1000}} \longrightarrow C_1 = 5.96 \longrightarrow J = 0.826$$

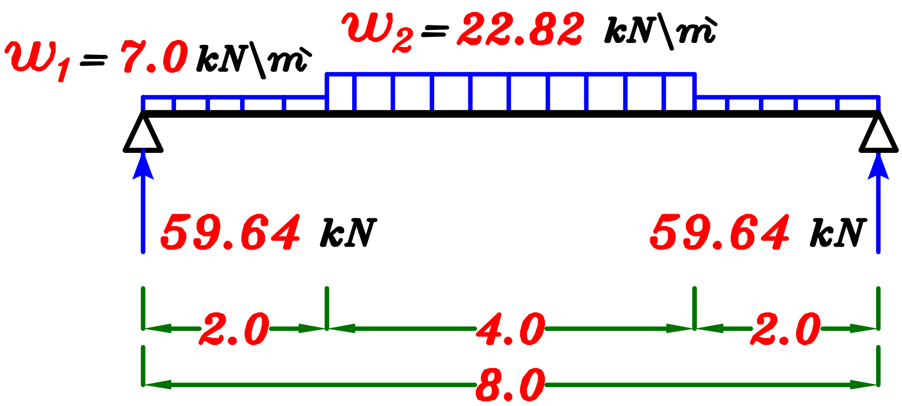
$$A_s = \frac{11.86 * 10^6}{0.826 * 360 * 130} = 306.8\ mm^2/m`$$

$$5\,\phi\,10\backslash m`$$

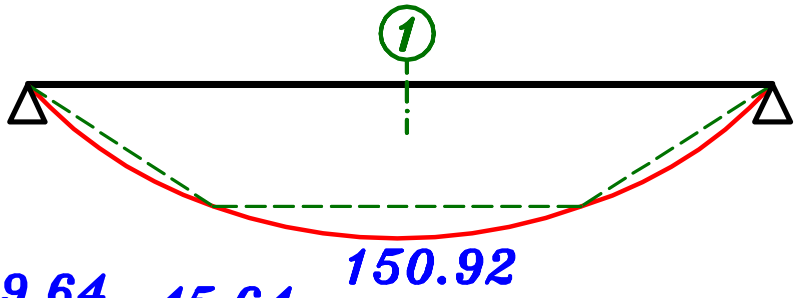
Loads on the Beam.

$w_1 = o.w._{(beam)} \simeq 7.0 \ kN\backslash m'$ (U.L.)

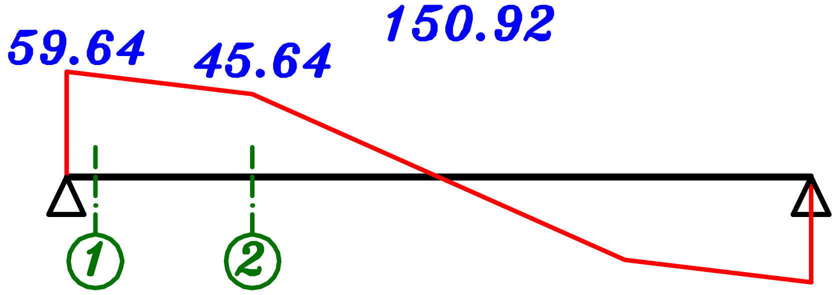
$w_2 = o.w._{(beam)} + R = 7.0 + 15.82 = 22.82 \ kN\backslash m'$



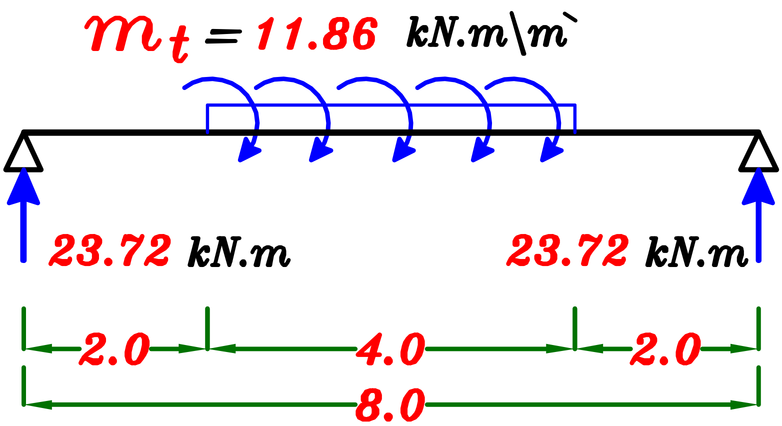
B.M.D.



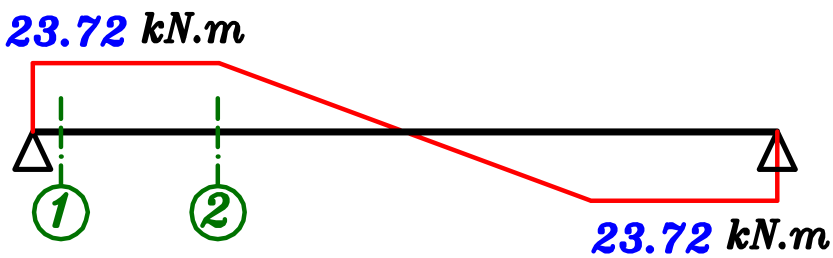
S.F.D.



T.M.

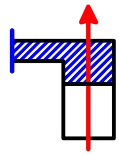


T.M.D.

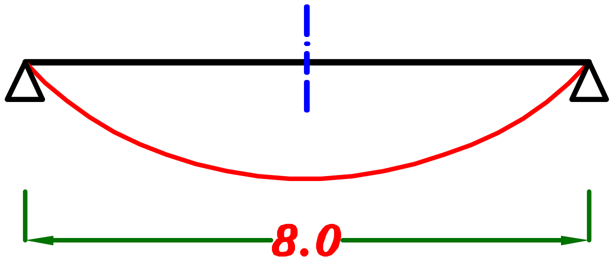


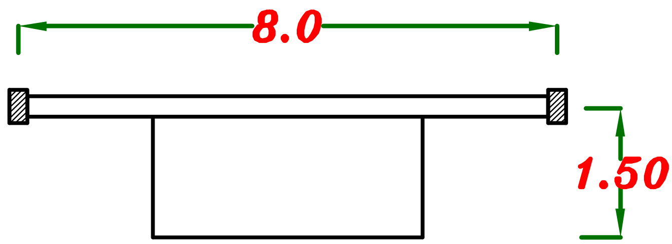
Dimensions of the Beam.

(L−sec.)



Take $b = 300$ mm





$$B = \left\{ \begin{array}{ll} C.L.-C.L. = 1.5\ m = 1500\ mm \\ 6\ t_s + b = 6 * 150 + 300 = 1200\ mm \\ K\dfrac{L}{10} + b = 1.0 * \dfrac{8000}{10} + 300 = 1100\ mm \end{array} \right\}$$

$$\boxed{B = 1100\ mm}$$

$$* \ t_{ben.} = C_1 \sqrt{\frac{M}{F_{cu}\,B}} = 6.0 \sqrt{\frac{150.92 * 10^6}{25 * 1100}} = 444.5\ mm \quad (L-sec.)$$

$$* \ t_{tor.} \simeq \frac{3\ M_t}{1.6 * b^2} = \frac{3 * 23.72 * 10^6}{1.6 * 300^2} = 494\ mm \qquad \boxed{t = 500\ mm}$$

Design the beam For bending. (300 * 500)

$M_{U.L.} = 150.92$ kN.m (L−sec.) , $d = 450$ mm

$$450 = C_1 \sqrt{\frac{150.92 * 10^6}{25 * 1100}} \longrightarrow C_1 = 6.04 \longrightarrow J = 0.826$$

$$- \text{Get} \quad A_s = \frac{M_{U.L.}}{J\ F_y\ d} = \frac{150.92 * 10^6}{0.826 * 360 * 450} = 1127.8\ mm^2$$

Check $A_{s_{min.}}$ $\qquad A_{s_{req.}} = 1127.8\ mm^2$

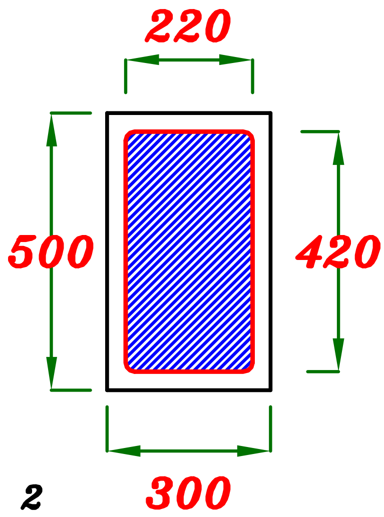
$$\mu_{min.}\,b\,d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\,d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 250 * 450 = 351.5\ mm^2$$

$$\therefore A_{s_{req.}} > \mu_{min.}\,b\,d \quad \therefore \text{Take } A_s = A_{s_{req.}} = 1127.8\ mm^2$$

Design the beam For Shear + Torsion.

Sec. 1

$$q_u = \frac{Q}{b\,d} = \frac{59.64 * 10^3}{300 * 450} = 0.441 \ N/mm^2$$



$$A_{oh} = 220 * 420 = 92400 \ mm^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 92400 = 78540 \ mm^2$$

$$P_h = 2 * 220 + 2 * 420 = 1280 \ mm$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{92400}{1280} = 72.18 \ mm$$

$$q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{23.72 * 10^6}{2 * 78540 * 72.18} = 2.09 \ N/mm^2$$

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98 \ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245 \ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85 \ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.441^2 + 2.09^2} = 2.136 \ N/mm^2 < q_{u\,max} \quad \therefore \text{o.k.}$$

$$\boxed{q_u < q_{cu} \ , \ q_{tu} > q_{t\,min}}$$

$\therefore$ Use RFT. For Torsion only.

* Stirrups.

$$\therefore A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\ \left(\frac{F_y}{\gamma_s}\right)} \qquad \therefore A_{str} = \frac{(23.72 * 10^6) * S_t}{(1.7)(92400)(240/1.15)}$$

$$\therefore \boxed{S_t = 1.382 * A_{str}}$$

* Take $\phi\, 8 \longrightarrow A_{str} = 50.3\ mm^2$

$$\therefore S_t = 1.382 * A_{str} = 1.382 * 50.3 = 69.51\ mm < 100\ mm$$

* Take $\phi\, 10 \longrightarrow A_{str} = 78.5\ mm^2$

$$\therefore S_t = 1.382 * A_{str} = 1.382 * 78.5 = 108.48\ mm > 100\ mm \quad \therefore o.k.$$

$$\therefore \text{No. of stirrups} \backslash m' = \frac{1000}{S} = \frac{1000}{108.48} = 9.21 = 10$$

$\therefore$ Use Closed Stirrups $\boxed{10\phi 10 \backslash m'}$ 2 branches.

---

* Longitudinal Bars.

$$S_t = \frac{1000}{10} = 100\ mm$$

$$A_{sl} = \frac{A_{str} * P_h}{S_t}\left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right) = \frac{(78.5 * 1280)}{100}\left(\frac{240}{360}\right) = 669.8\ mm^2$$

$$\therefore \frac{A_{sl}}{4} = \frac{669.8}{4} = 167.45\ mm^2$$

Check IF the Stirrups $5\phi 10\backslash m'$ is safe.

Sec.②

$$q_u = \frac{Q}{b\,d} = \frac{45.64 * 10^3}{300 * 450} = 0.338 \ N/mm^2$$

$$q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{23.72 * 10^6}{2 * 78540 * 72.18} = 2.09 \ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.338^2 + 2.09^2} = 2.11 \ N/mm^2 < q_{u\,max} \quad \therefore o.k.$$

$$\boxed{q_u < q_{cu} \ , \ q_{tu} > q_{t\,min}}$$

$\therefore$ The Stirrups will resist Torsion only.

* **Check Stirrups.** $\because \ A_{str} = \dfrac{M_{tu} \ S_t}{(1.7) \ A_{oh} \left(\frac{F_y}{\delta_s}\right)}$

$$\therefore \ A_{str} = \frac{(23.72 * 10^6) * S_t}{(1.7)(92400)(360/1.15)} \qquad \therefore \ \boxed{S_t = 2.073 * A_{str}}$$

* The given $\phi\ 10 \longrightarrow A_{str} = 78.5 \ mm^2$

$$\therefore \ S_t = 2.073 * A_{str} = 2.073 * 78.5 = 162.7 \ mm$$

$$\therefore \text{No. of stirrups required}\backslash m' = \frac{1000}{S} = \frac{1000}{162.7} = 6.14 > 5.0$$

$\therefore$ the stirrups $\boxed{5\phi 10\backslash m'}$ is not enough.

We Should increase the slab reinforcement to $\boxed{7\phi 10\backslash m'}$

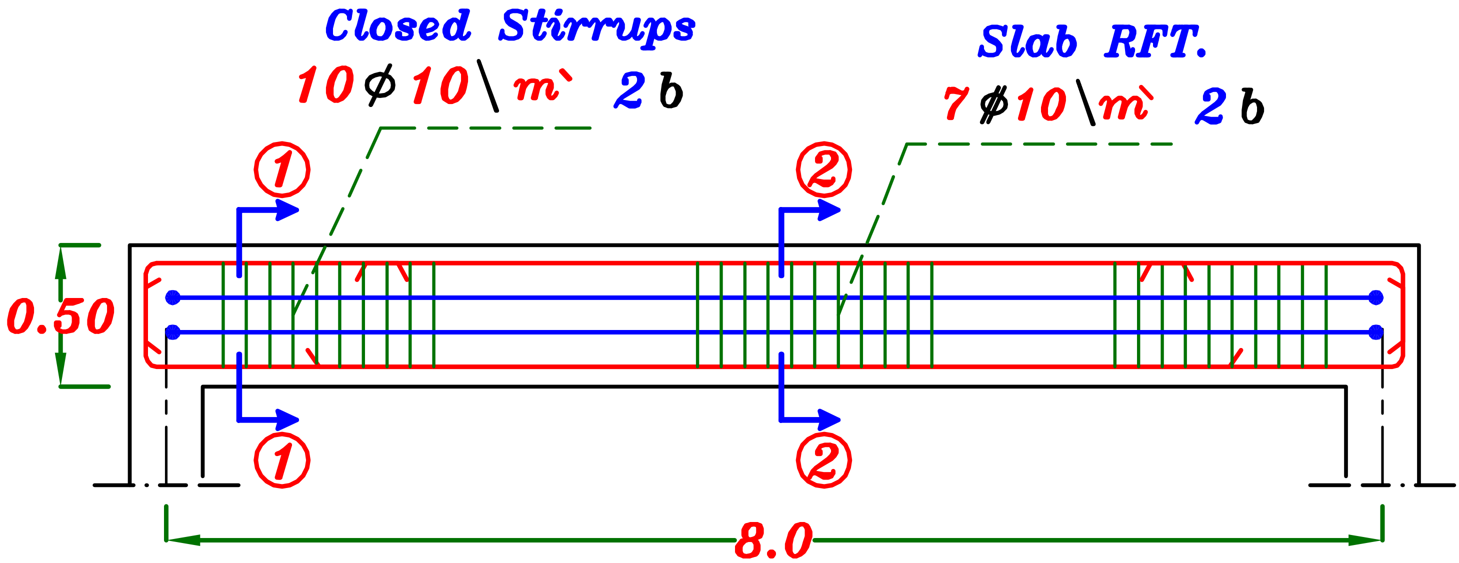
* **Longitudinal Bars.** $\quad S_t = \dfrac{1000}{7} = 142.85 \ mm$

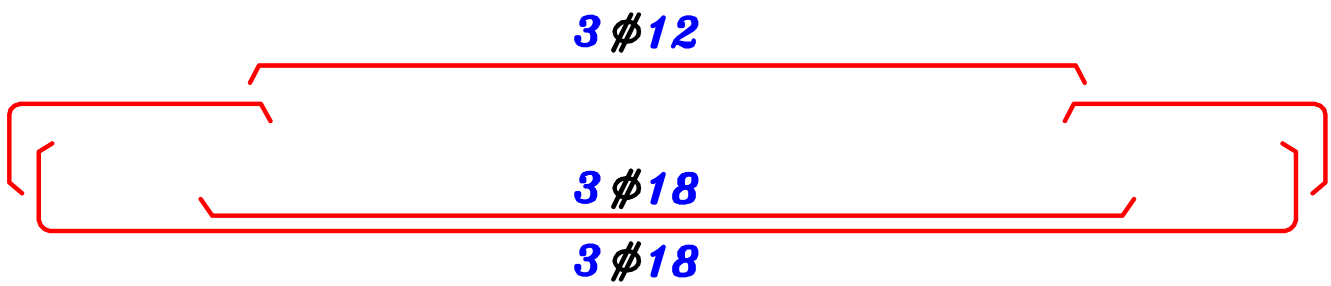
$$A_{sl} = \frac{A_{str} * P_h}{S_t} \left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right) = \frac{(78.5 * 1280)}{142.85} \left(\frac{360}{360}\right) = 703.39 mm^2$$

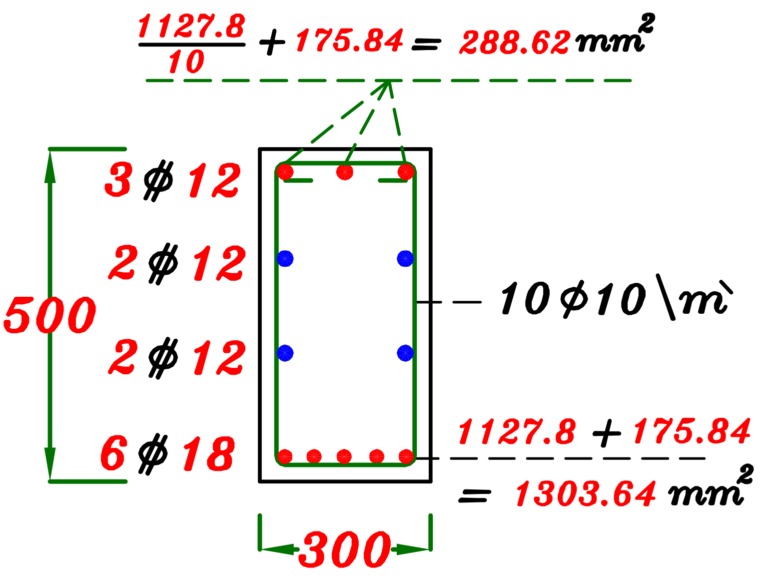
$$\therefore \ \frac{A_{sl}}{4} = \frac{703.39}{4} = 175.84 \ mm^2$$

ملحوظه نأخذ قيمه A_{sl} الاكبر فى كل القطاعات التى فى الكمره .

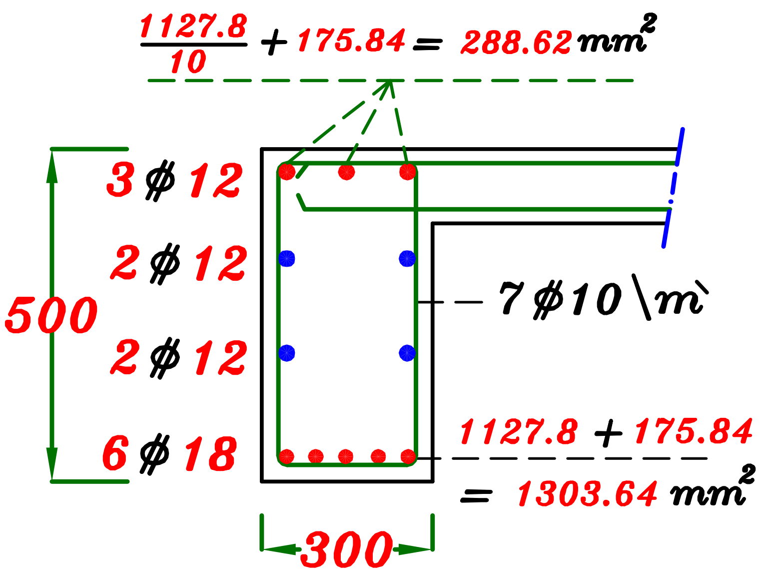
$$\frac{A_{sl}}{4} = 175.84\ mm^2$$



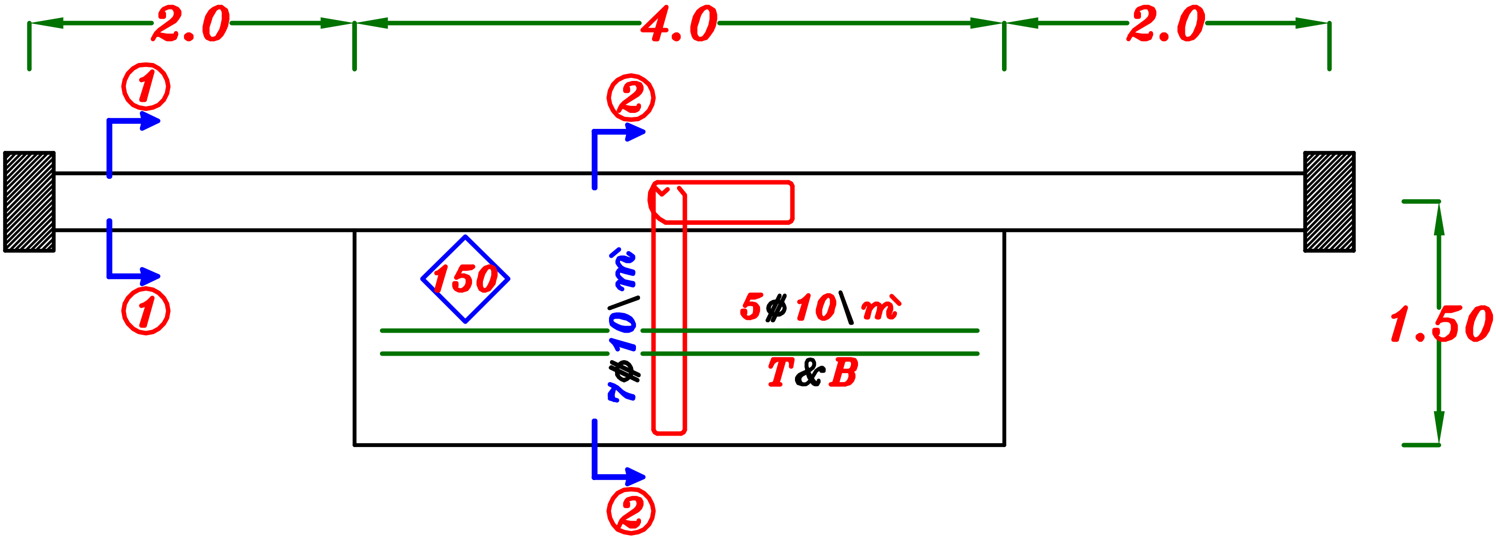


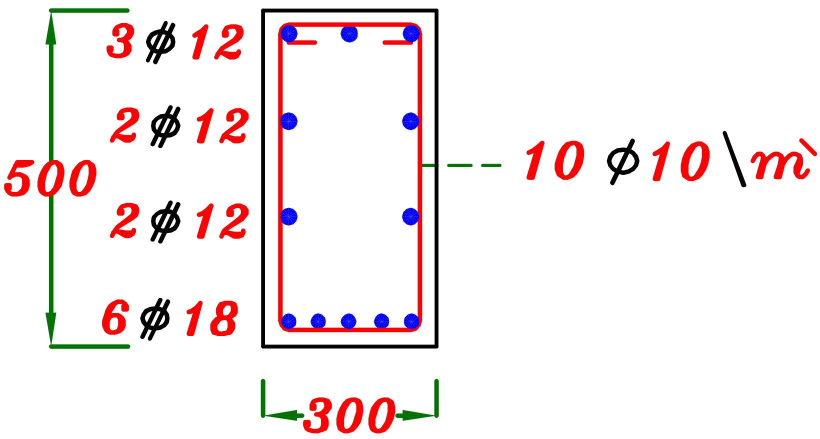


Sec. (1−1)

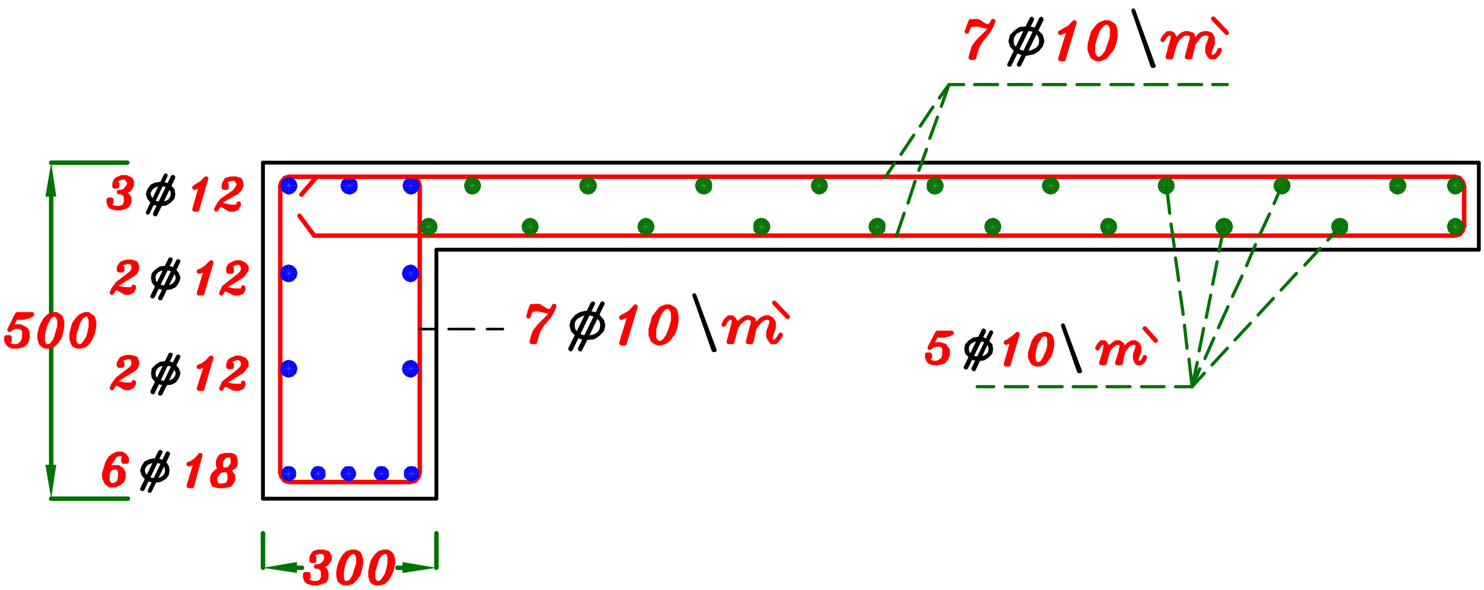


Sec. (2−2)


2.0
4.0
2.0
1
2
150
7∅10\m`
5∅10\m`
T&B
1.50

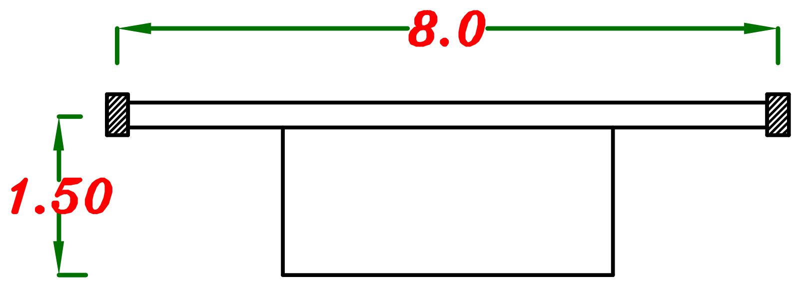

3∅12
2∅12
2∅12
6∅18
500
10 ∅10\m`
300

Sec. (1–1)

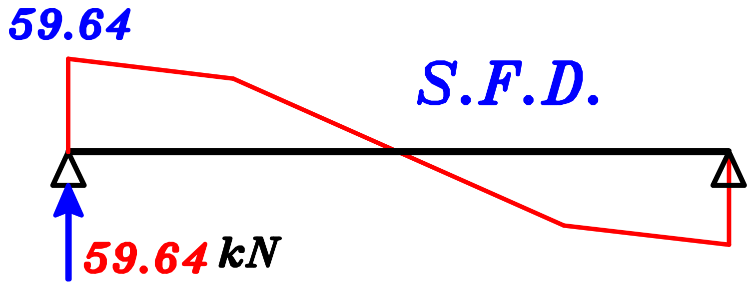

7∅10\m`
3∅12
2∅12
2∅12
6∅18
500
7∅10\m`
5∅10\m`
300

Sec. (2–2)

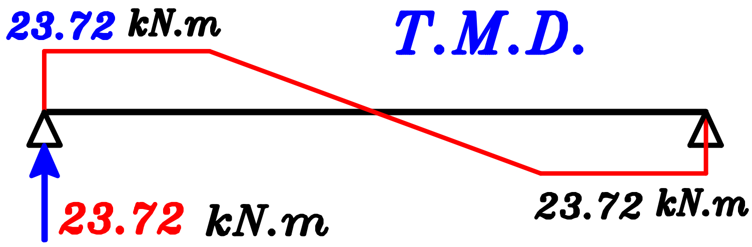
Design of the Column.

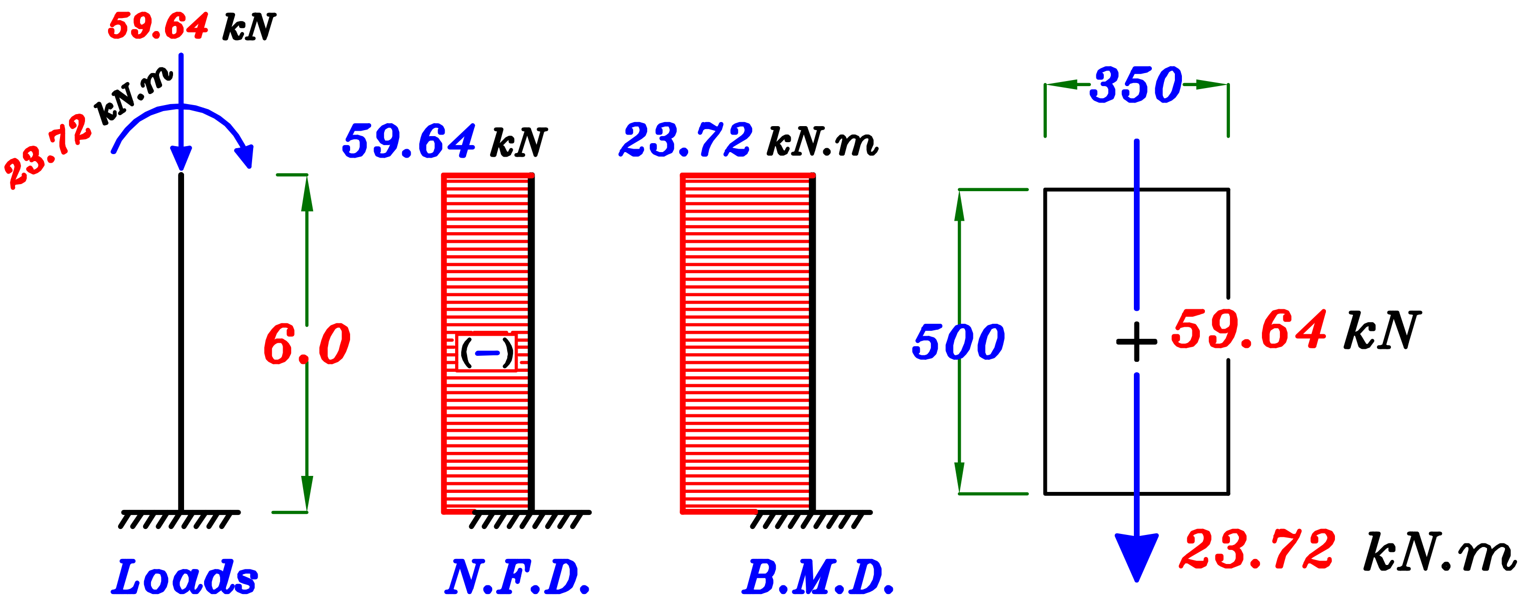


Reaction of S.F.D.
=
Load on the column.



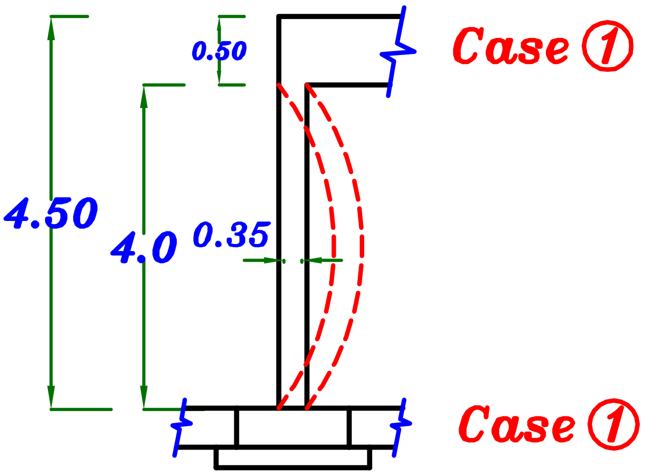
Reaction of T.M.D.
=
Bending on the column.





Check Buckling.

① In plane.

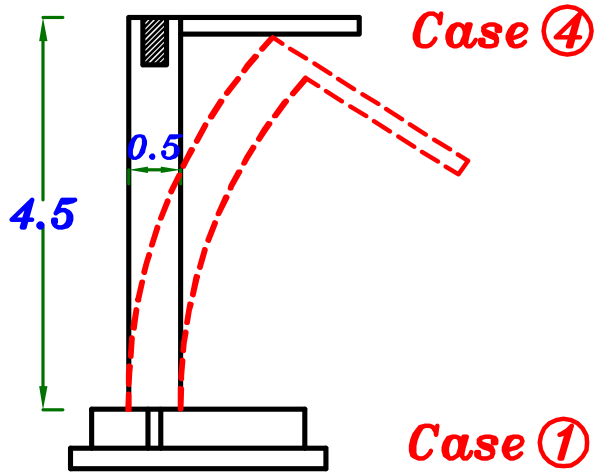


Upper Condition Case ①
Lower Condition Case ①
$\Big\}\ K = 1.2$

$H_o = 4.0$ m

$$\lambda_{b_{in}} = \frac{1.2 * 4.0}{0.35} = 13.7 > 10$$

② Out of plane.



Upper Condition Case ④
Lower Condition Case ①
$\Big\}\ K = 2.2$

$H_o = 4.50$ m

$$\lambda_{b_{out}} = \frac{2.2 * 4.5}{0.50} = 19.8 > 10$$

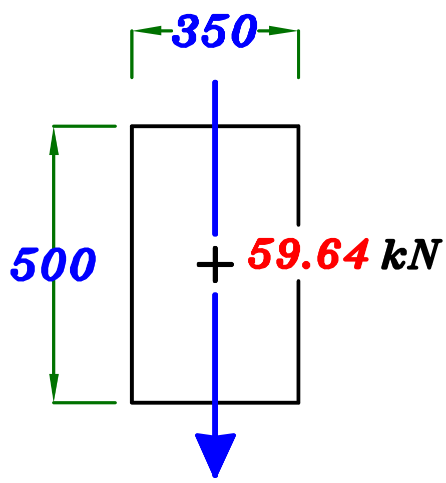
Take the bigger value of $\lambda_b = 19.8$ (Out of plane.)

$$\delta = \frac{(\lambda_b)^2 * t}{2000} = \frac{19.8^2 * 0.5}{2000} = 0.098\ m$$

$$M_{add.} = P * \delta = 59.64 * 0.098 = 5.84\ kN.m$$

$$\because\ M_{des.} = M_{ext.} + M_{add.}$$

$$\therefore\ M_{des.} = 23.72 + 5.84 = 29.56\ kN.m$$



$23.72 + 5.84 = 29.56$ kN.m

Design the Sec.

$$e = \frac{M}{P} = \frac{29.56}{59.64} = 0.495 \ m \qquad \therefore \frac{e}{t} = \frac{0.495}{0.50} = 0.991 > 0.5 \xrightarrow{use} e_s$$

$$e_s = e + \frac{t}{2} - c = 0.495 + \frac{0.5}{2} - 0.05 = 0.695 \ m$$

$$M_s = P * e_s = 59.64 * 0.695 = 41.45 \ kN.m$$

$$\therefore 450 = C_1 \sqrt{\frac{41.45 * 10^6}{25 * 350}} \longrightarrow C_1 = 6.53 \longrightarrow J = 0.826$$

$$\therefore A_s = \frac{M_s}{J F_y d} - \frac{P_{U.L.}}{(F_y \backslash \gamma_s)} = \frac{41.45 * 10^6}{0.826 * 360 * 450} - \frac{59.64 * 10^3}{(360 \backslash 1.15)} = 119.24 \ mm^2$$

$$A_{s_{min}} = \frac{0.25 + 0.052 \lambda_{max}}{100} * b * t$$

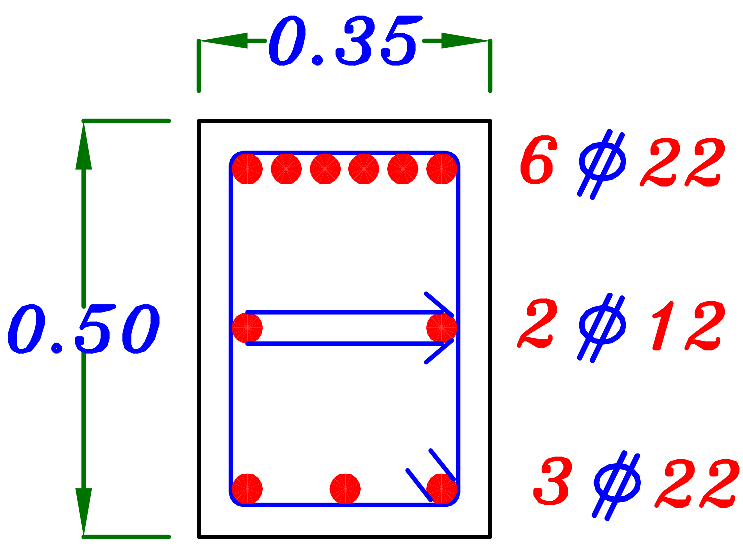
$$= \frac{0.25 + 0.052 (19.8)}{100} * 350 * 500 = 2239.3 \ mm^2 > A_s$$

$$\therefore \text{Take } A_s = A_{s_{min}} = 2239.3 \ mm^2 \qquad 6 \phi 22$$

$$n = \frac{b - 25}{\phi + 25} = \frac{350 - 25}{22 + 25} = 6.91 = 6.0 \text{ bars}$$

$$\text{Stirrup Hangers} = 0.4 A_s = 0.4 * 2239.3 = 895.7 \ mm^2$$

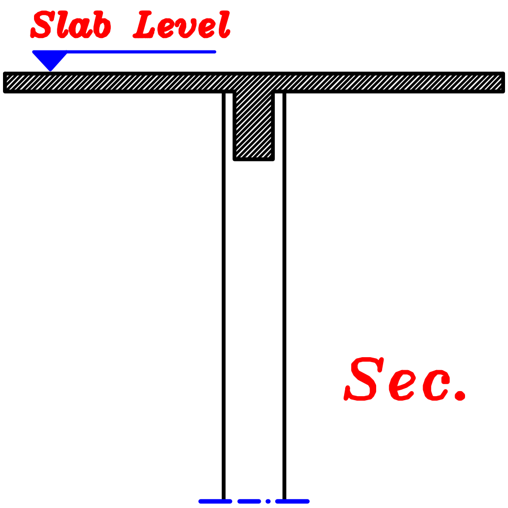
$$3 \phi 22$$

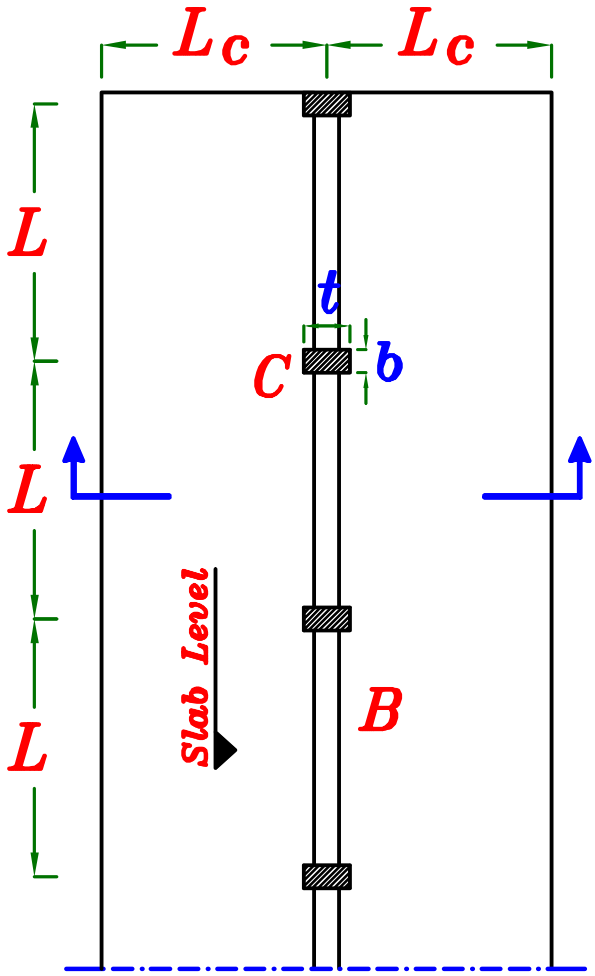


Example.

1- Design the beam B

2- Design the column C

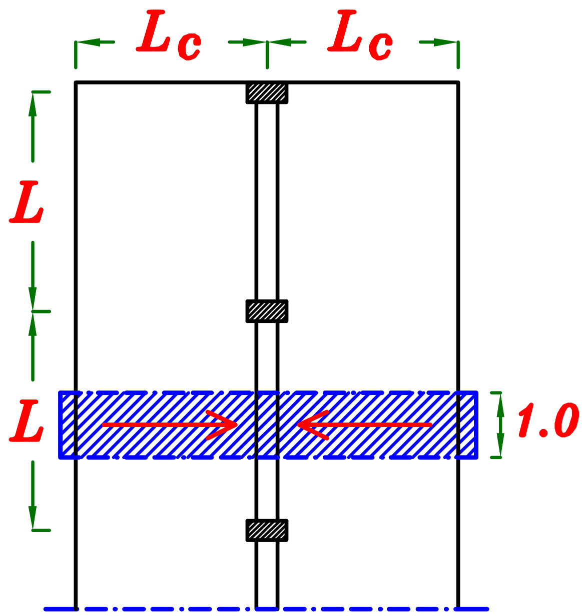


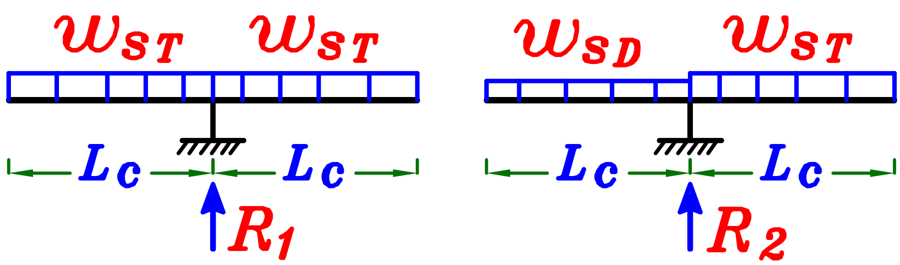


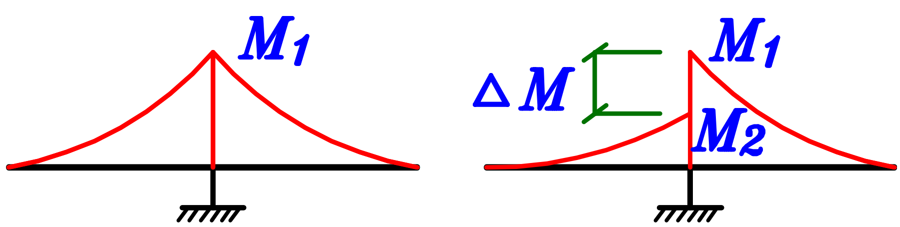
By taking strip in the slab.

$$w_{ST} = 1.4\,(t_s\,\gamma_c + F.C.) + 1.6\,(L.L.)$$

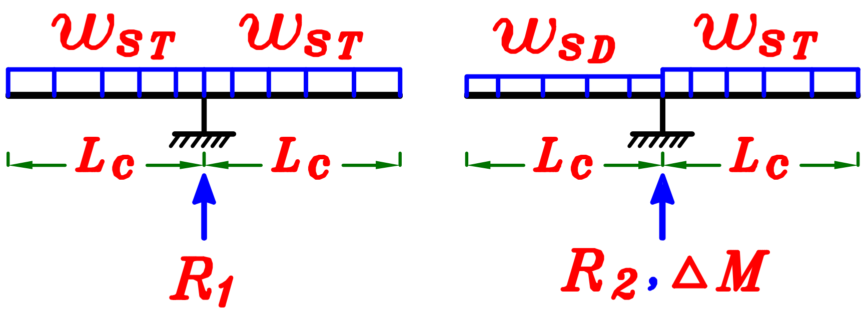
$$w_{SD} = 0.9\,(t_s\,\gamma_c + F.C.)$$



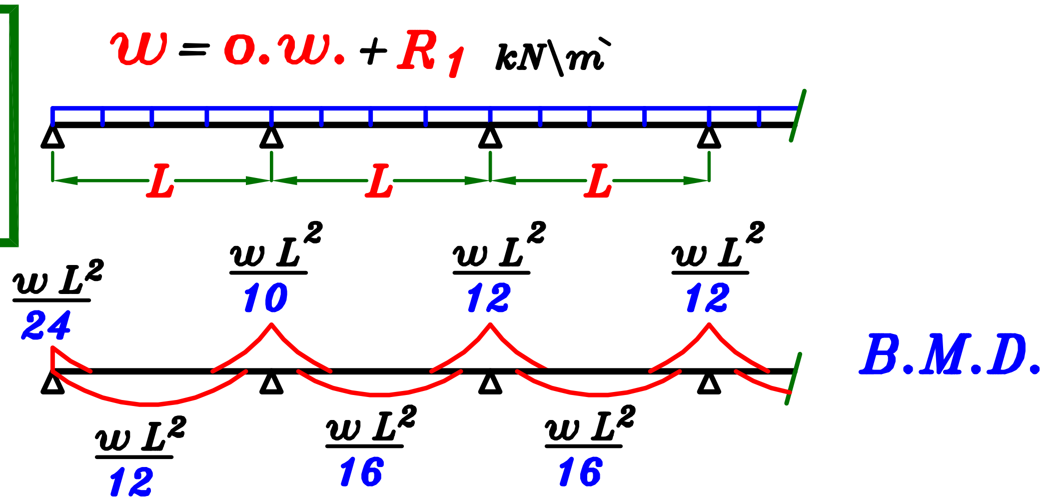




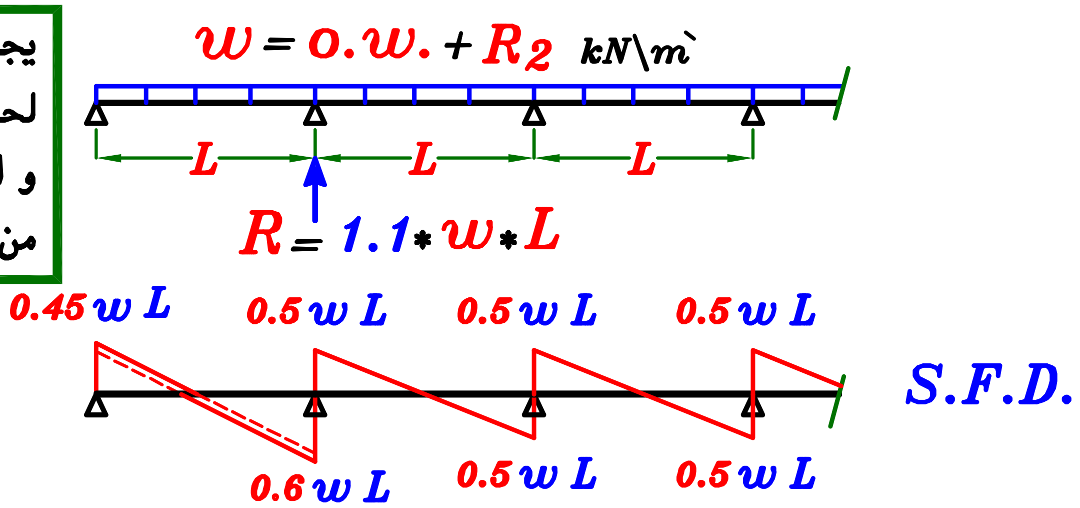
Loads on Beam B

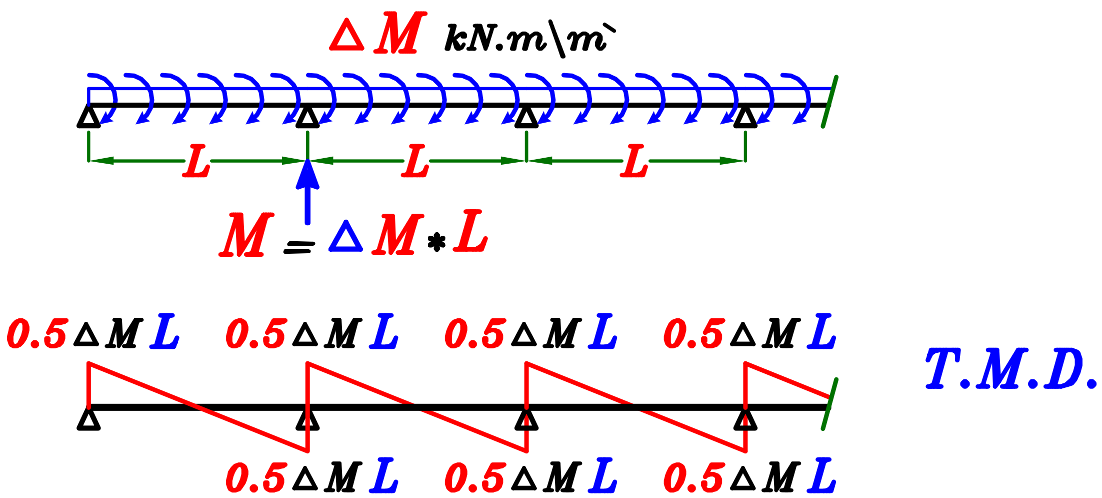


عند حساب ال **B.M.**
للكمره نأخذ قيمه R_1
لنحدد اكبر **B.M.**



يجب ان تؤخذ الاحمال
لحساب ال **Shear**
و ال **Torsion**
من نفس حاله التحميل





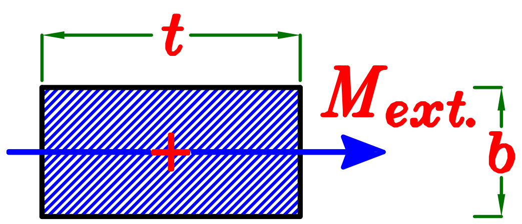
Column C

VL. Load on Column. = Reaction From Loads

$$= 1.1 * w * L \quad = 1.1 * (o.w. + R_2) * L$$

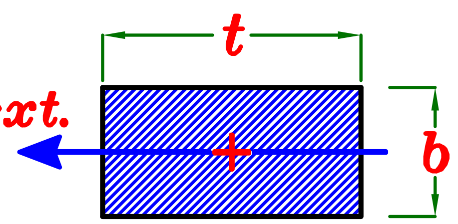
Bending Moment on Column = Reaction From Torsion.

$$= M_{ext.} = \Delta M * L$$



OR

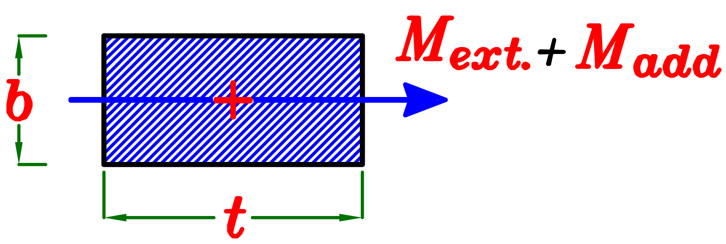
حسب حالات التحميل



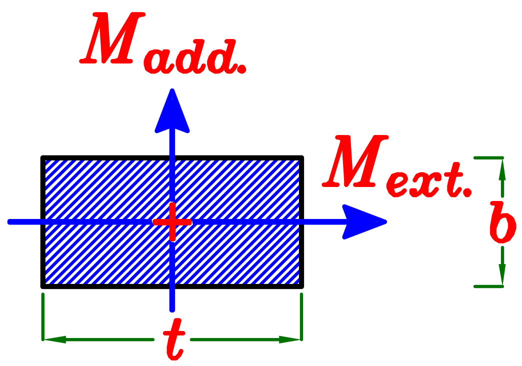
Calculate $M_{add.}$ From Buckling

Design the Sec.

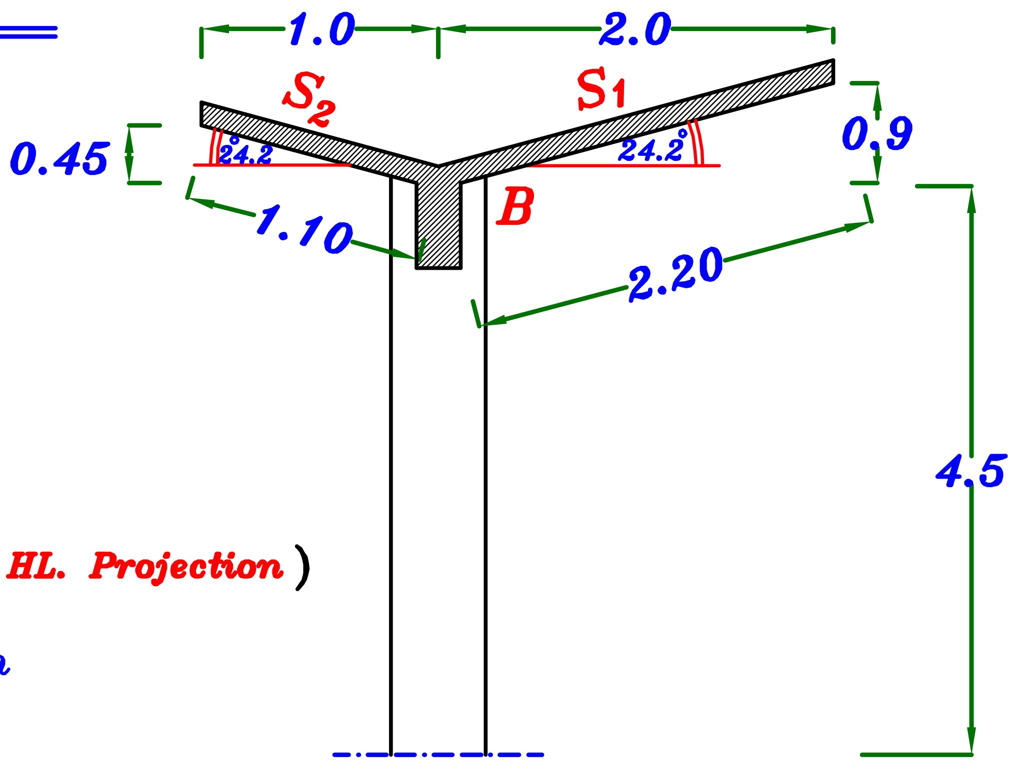
IF $M_{add.}$ In Plane



IF $M_{add.}$ Out of Plane



Example.



Data.

$F_{cu} = 25 \ N\backslash mm^2$

$F_y = 360 \ N\backslash mm^2$

$F.C. = 2.5 \ kN\backslash m^2$

$L.L. = 1.0 \ kN\backslash m^2$ (*HL. Projection*)

$Spacing = 5.0 \ m$

Req.

1. Complete design of the slab, beam & the column.
2. Draw the details of RFT in plan & cross-sections.

Solution.

For (S_1) $\quad t_s = \dfrac{L_c}{10} = \dfrac{2200}{10} = 220 \ mm$ $\quad \boxed{t_{s1} = 220 \ mm}$

For (S_2) $\quad t_s = \dfrac{L_c}{10} = \dfrac{1100}{10} = 110 \ mm$ $\quad \boxed{t_{s2} = 120 \ mm}$

Case of Total Load. (T.L.)

$(w_{s1})_T = 1.4(0.22*25 + 2.5) + 1.6(1.0) \ Cos\,24.2^\circ = 12.65 \ kN\backslash m^2$

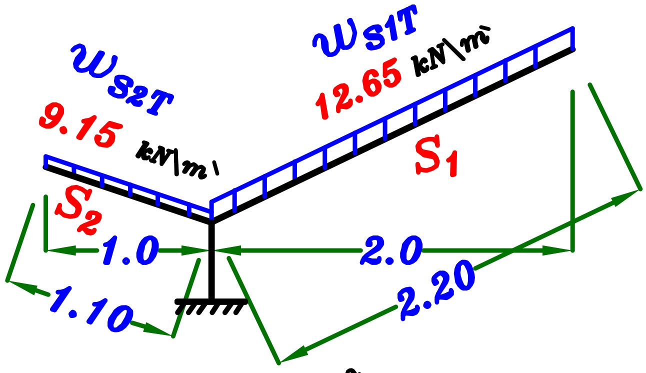
$(w_{s2})_T = 1.4(0.12*25 + 2.5) + 1.6(1.0) \ Cos\,24.2^\circ = 9.15 \ kN\backslash m^2$

Case of Dead Load. (D.L.)

$(w_{s1})_D = 0.9(0.22*25 + 2.5) = 7.20 \ kN\backslash m^2$

$(w_{s2})_D = 0.9(0.12*25 + 2.5) = 4.95 \ kN\backslash m^2$

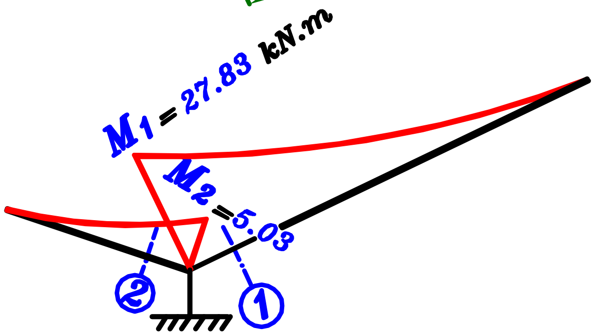
Loads to design the Slabs.



$$M_1 = 12.65 * 2.20 * \frac{2.0}{2} = 27.83 \text{ kN.m\m`}$$

$$M_2 = 9.15 * 1.10 * \frac{1.0}{2} = 5.03 \text{ kN.m\m`}$$

Design of Slab. (S_1)



Sec. 1

$M_{U.L.} = 27.83$ kN.m\m

, $t_s = 220$ mm , $d = 200$ mm

$$200 = C_1\sqrt{\frac{27.83 * 10^6}{25 * 1000}} \longrightarrow C_1 = 5.99 \longrightarrow J = 0.826$$

$$A_s = \frac{27.83 * 10^6}{0.826 * 360 * 200} = 467.9 \text{ mm}^2/\text{m`}$$

$5\phi12\backslash$m`

Design of Slab. (S_2)

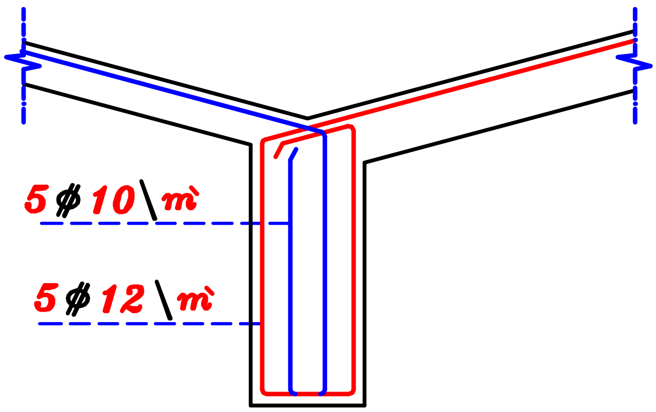
Sec. 2

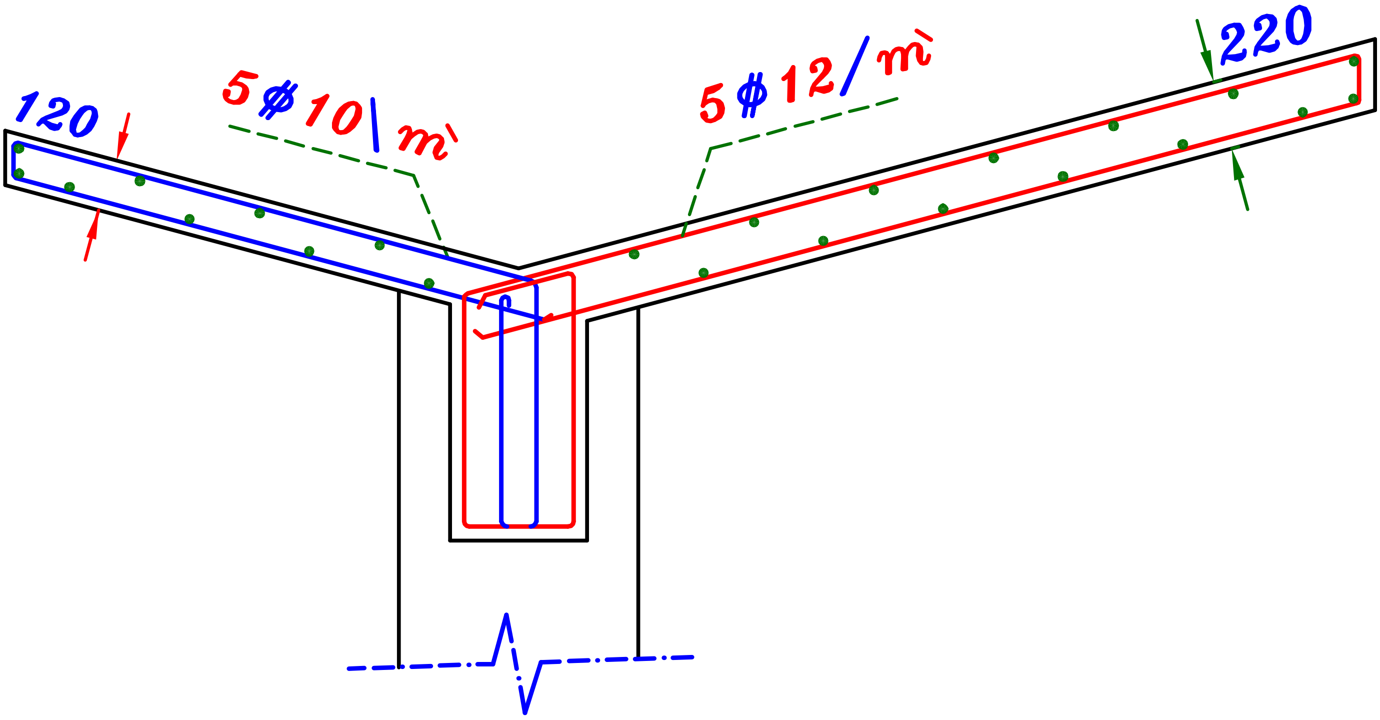
$M_{U.L.} = 5.03$ kN.m\m , $t_s = 120$ mm , $d = 100$ mm

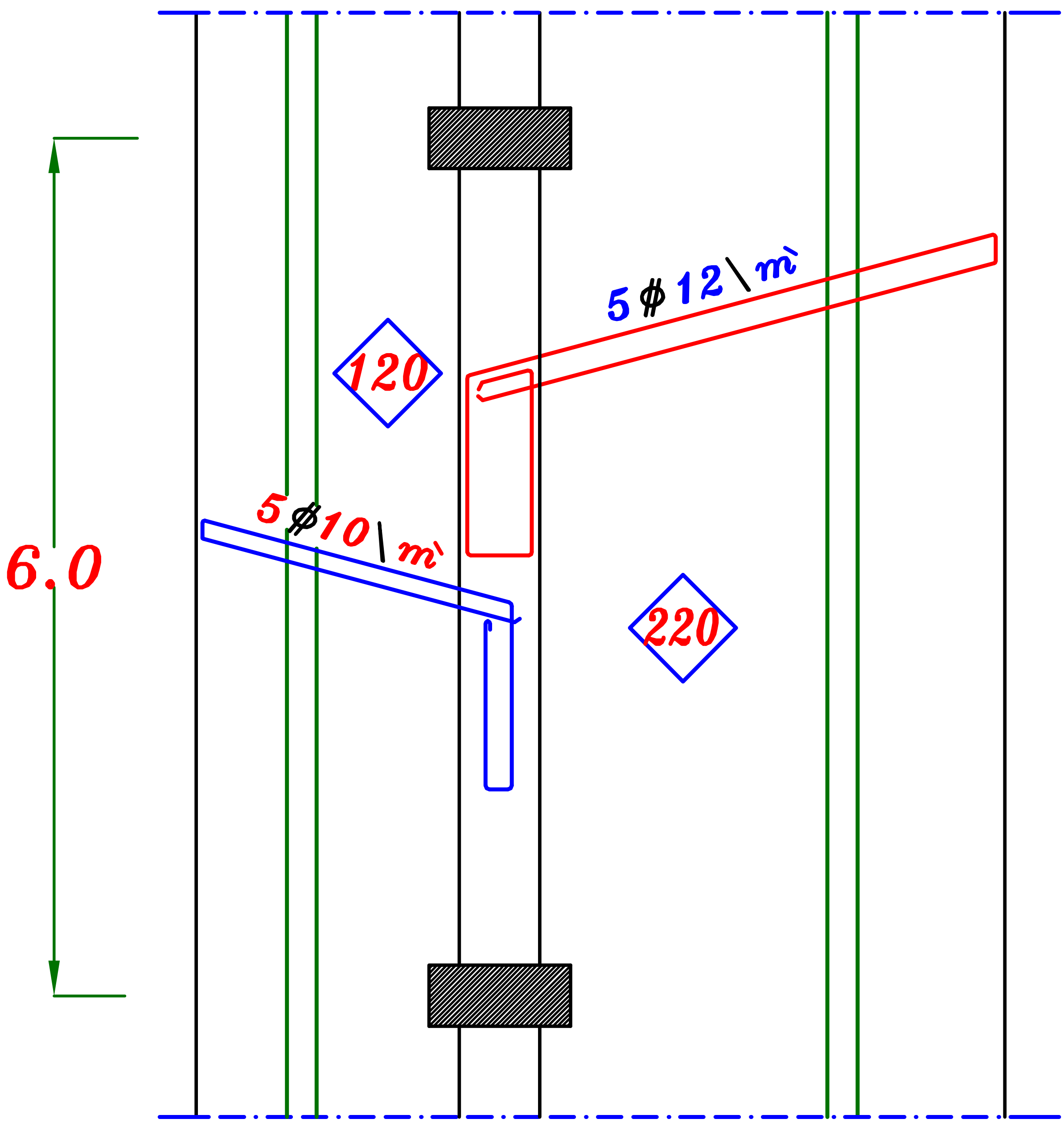
$$100 = C_1\sqrt{\frac{5.03 * 10^6}{25 * 1000}} \longrightarrow C_1 = 7.05 \longrightarrow J = 0.826$$

$$A_s = \frac{5.03 * 10^6}{0.826 * 360 * 100} = 169.1 \text{ mm}^2/\text{m`}$$

$5\phi10\backslash$m`




120
5 ϕ 10\ m`
5 ϕ 12/ m`
220

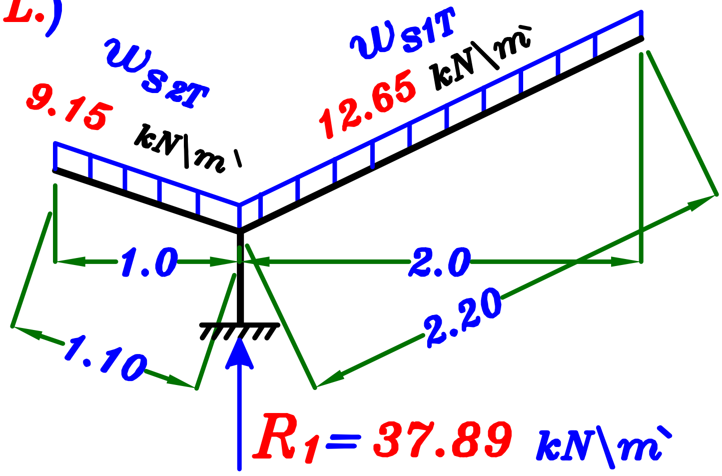

6.0
5 ϕ 12\ m`
120
5 ϕ10\ m`
220

Design of the beam.

1 – Draw B.M.D. , S.F.D. & T.M.D.

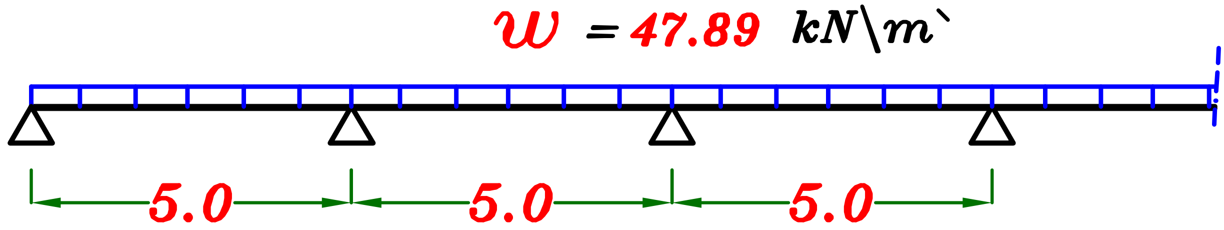
To Draw B.M.D. For the Beam.

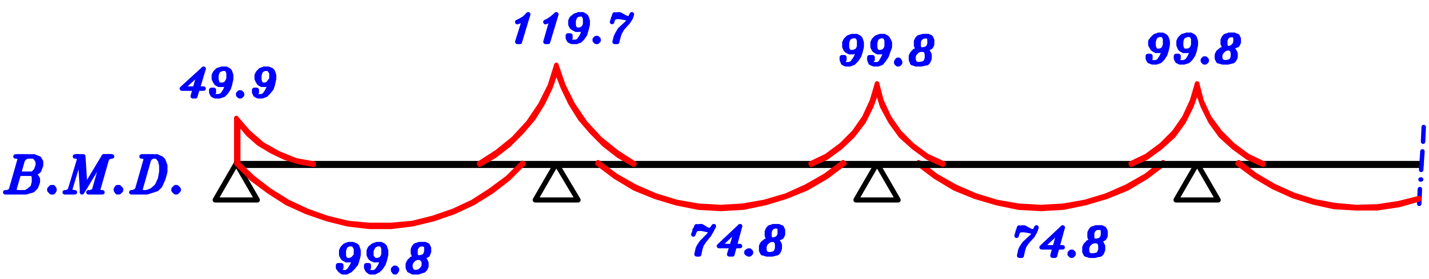
$o.w._{(beam)} \simeq 10$ kN\m` (U.L.)



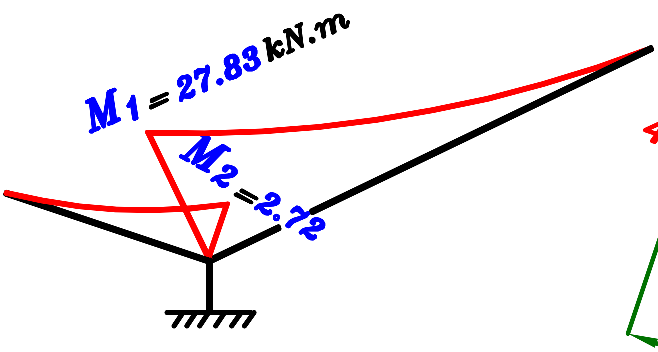
$$w = o.w._{(beam)} + R_1$$

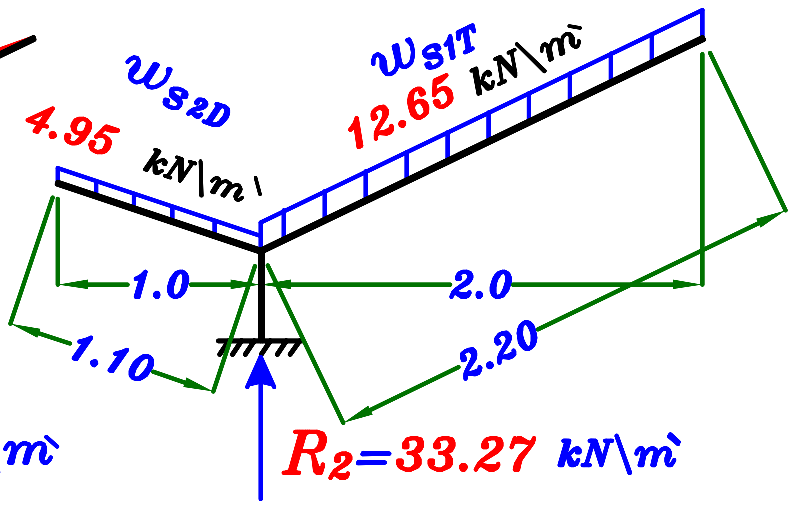
$$= 10 + 37.89 = 47.89 \text{ kN\m`}$$





To Draw S.F.D. & T.M.D.. For the Beam.



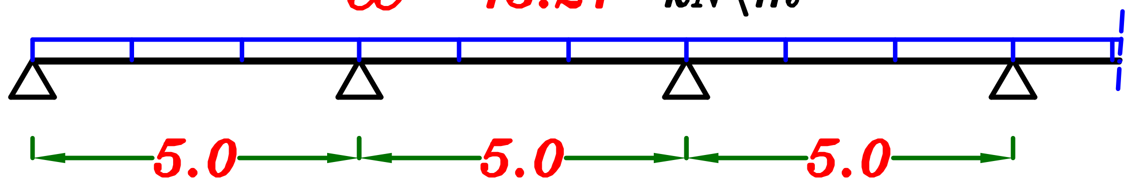


$\triangle M = 25.11$ kN.m\m`

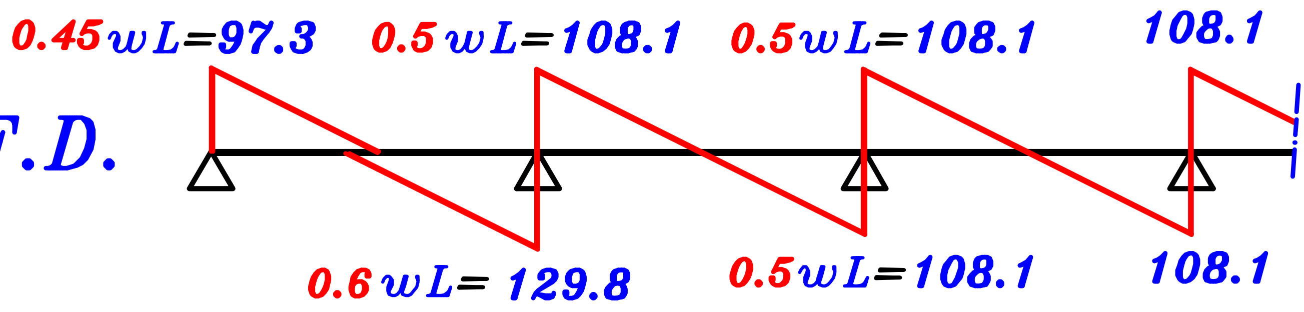
$$w = o.w._{(beam)} + R_2 = 10 + 33.27 = 43.27 \text{ kN\textbackslash m`}$$

$$w = 43.27 \text{ kN\textbackslash m`}$$

Load



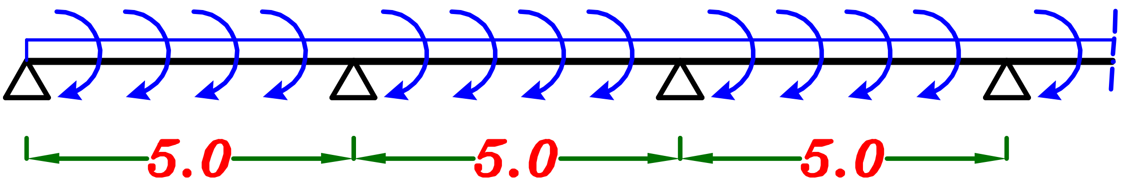
S.F.D.



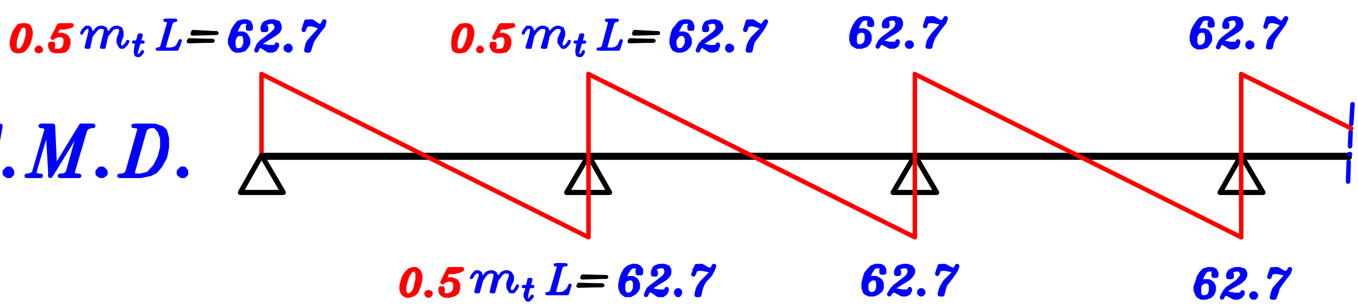
$$\Delta M = M_1 - M_2 = 27.83 - 2.72 = 25.11 \text{ kN.m\textbackslash m`}$$

$$m_t = \Delta M = 25.11 \text{ kN.m\textbackslash m`}$$

Torsion

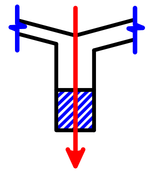


T.M.D.



Dimensions of the Beam.

(R-sec.)



Take $b = 400$ mm

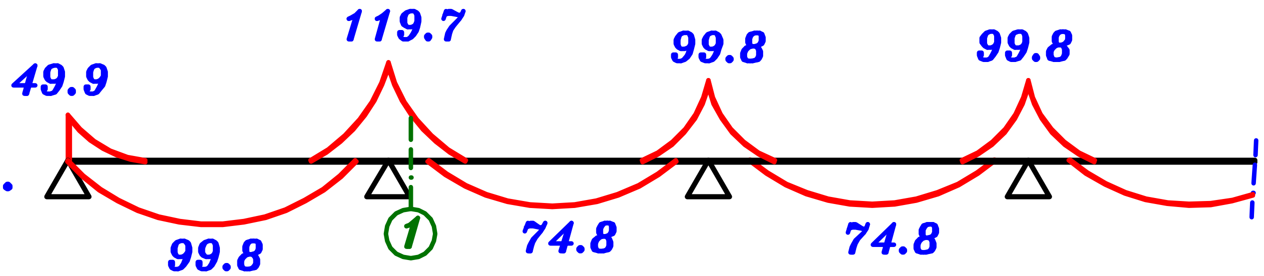
$$* \; t_{ben.} = C_1 \sqrt{\frac{M}{F_{cu} B}} = 3.5 \sqrt{\frac{119.7 * 10^6}{25 * 400}} = 382.9 \text{ mm (R-sec.)}$$

$$* \; t_{tor.} \simeq \frac{3 M_t}{1.6 * b^2} = \frac{3 * 62.7 * 10^6}{1.6 * 400^2} = 734.7 \text{ mm} \qquad \boxed{t = 750 \text{ mm}}$$

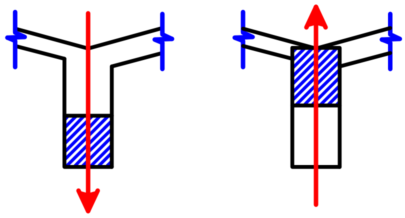
Design the beam For bending.

(400 * 750)

B.M.D.



All Sections are R-Sec.



Sec 1

$$M_{U.L.} = 119.7 \text{ kN.m}$$

$$700 = C_1 \sqrt{\frac{119.7 * 10^6}{25 * 400}} \longrightarrow C_1 = 6.40 \longrightarrow J = 0.826$$

$$A_s = \frac{119.7 * 10^6}{0.826 * 360 * 700} = 575.0 \text{ mm}^2$$

Check $A_{s\,min.}$ $\qquad A_{s\,req.} = 575.0 \text{ mm}^2$

$$\mu_{min.}\, b\, d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 400 * 700 = 875 \text{ mm}^2$$

$$\therefore \mu_{min.}\, b\, d > A_{s\,req.} \xrightarrow{\text{Use}} A_{s\,min.}$$

$$A_{s\,min.} = 0.225 * \frac{\sqrt{F_{cu}}}{F_y}\, b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 400 * 700 = 875$$

$$1.3\, A_{s\,req.} = 1.3 * 575.0 = 747.5$$

الأقل $= 747.5$

st. 360/520 $\qquad \frac{0.15}{100}\, b\, d = \frac{0.15}{100} * 400 * 700 = 420 \text{ mm}^2$

الأكبر $= 747.5 \text{ mm}^2$

Check if the Stirrups $5\phi10\backslash m' + 5\phi12\backslash m'$ are safe.

Sec. ①

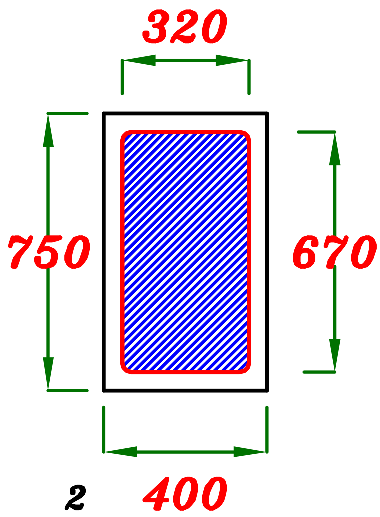
$$q_u = \frac{Q}{b\,d} = \frac{129.8 * 10^3}{400 * 700} = 0.463 \ N/mm^2$$

$$A_{oh} = 320 * 670 = 214400 \ mm^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 214400 = 182240 \ mm^2$$

$$P_h = 2 * 320 + 2 * 670 = 1980 \ mm$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{214400}{1980} = 108.28 \ mm$$



$$q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{62.7 * 10^6}{2 * 182240 * 108.28} = 1.59 \ N/mm^2$$

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98 \ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245 \ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85 \ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.463^2 + 1.59^2} = 1.656 \ N/mm^2 < q_{u\,max} \quad \therefore \text{o.k.}$$

$$\boxed{q_u < q_{cu} \ , \ q_{tu} > q_{t\,min}}$$

$\therefore$ The Stirrups will resist Torsion only.

$$A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\left(\frac{F_y}{\gamma_s}\right)} = \frac{(62.7 * 10^6) * S_t}{(1.7)(214400)(360/1.15)}$$

$$\therefore \boxed{S_t = 1.819 * A_{str}}$$

* The given $\phi\ 12 \longrightarrow A_{str} = 113\ mm^2$

$\therefore S_t = 1.684 * A_{str} = 1.819 * 113 = 205.54\ mm$

$\therefore$ No. of stirrups required\m` $= \frac{1000}{S} = \frac{1000}{205.54} = 4.86 < 5.0$

$\therefore$ the stirrups $\boxed{5\phi 12\backslash m`}$ is enough to resisth the Torsion.

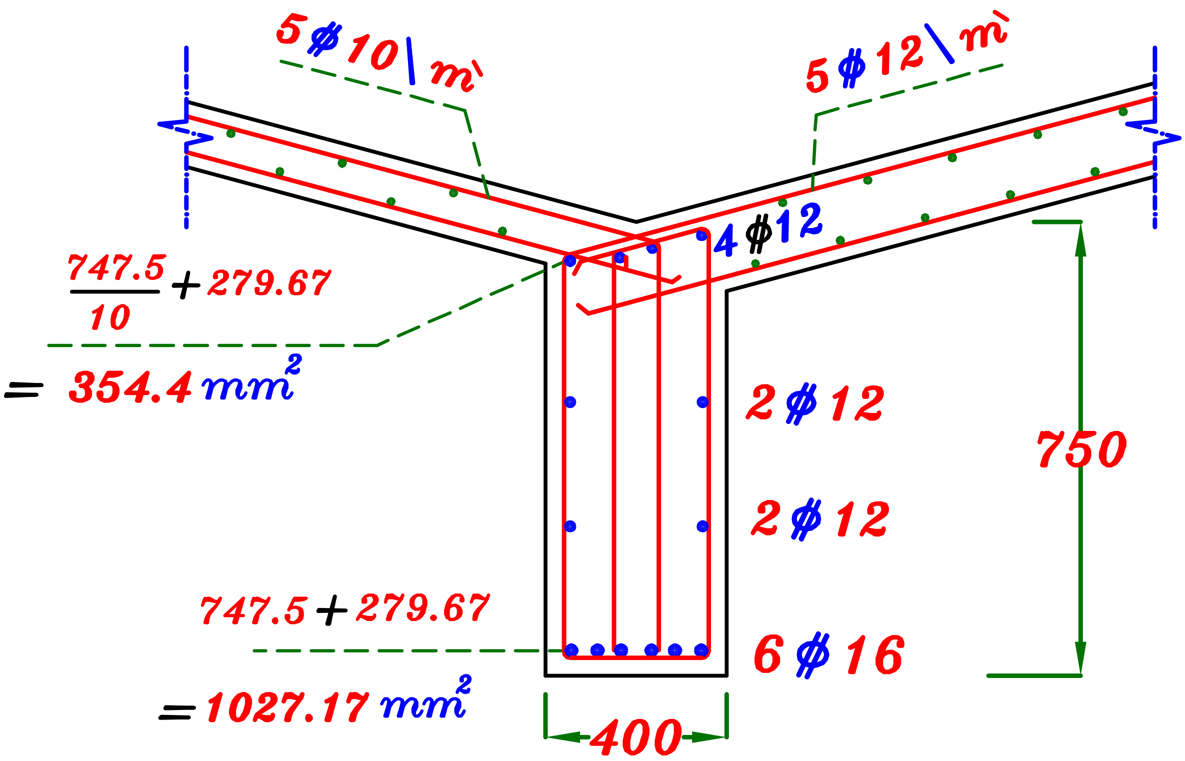
---

* **Longitudinal Bars.**

$$S_t = \frac{1000}{5} = 200\ mm$$

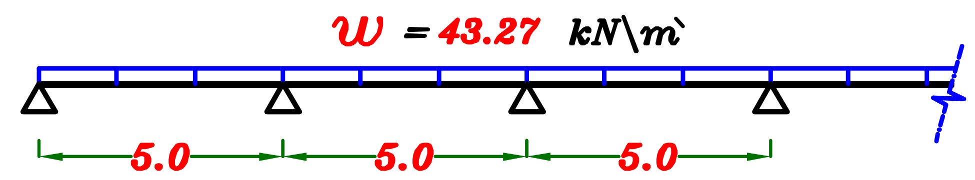
$$A_{sl} = \frac{A_{str} * P_h}{S_t}\left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right) = \frac{(113 * 1980)}{200}\left(\frac{360}{360}\right) = 1118.7\ mm^2$$

$$\therefore \frac{A_{sl}}{4} = \frac{1118.7}{4} = 279.67\ mm^2$$

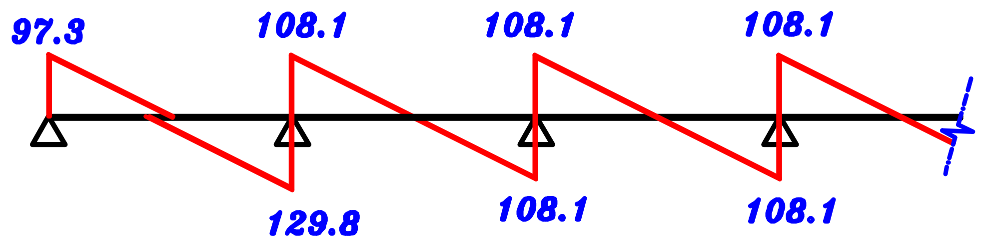


Normal Force & Bending Moment on the column.

Load



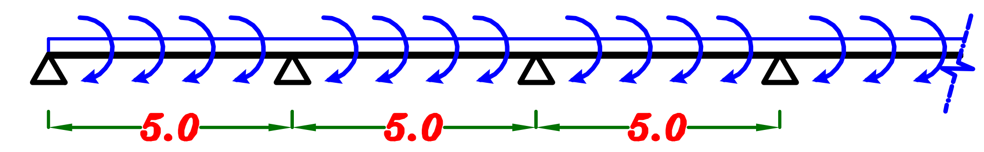
S.F.D.
For the beam.



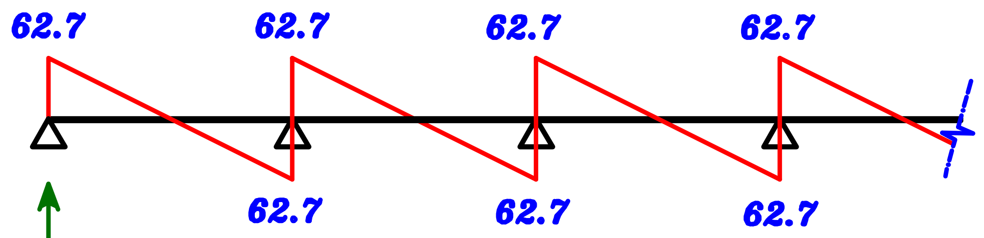
Reaction of S.F.D.
=
Load on the column.

$m_t = \Delta M = 25.11$ kN.m\m`

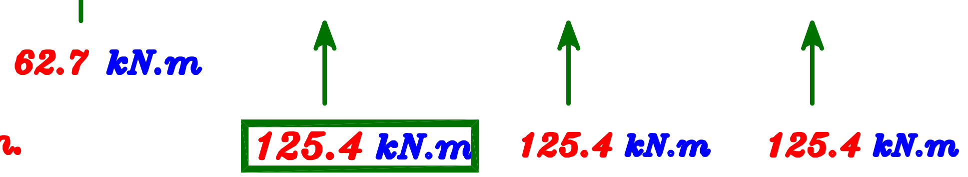
Torsion

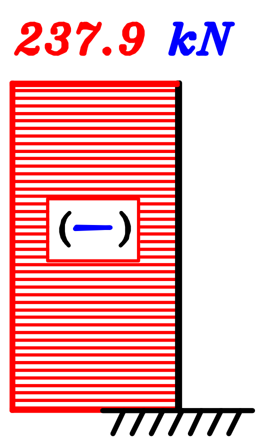


T.M.D.
For the beam.

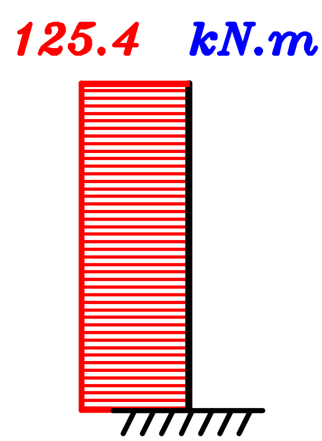


Reaction of T.M.D.
=
Bending on the column.

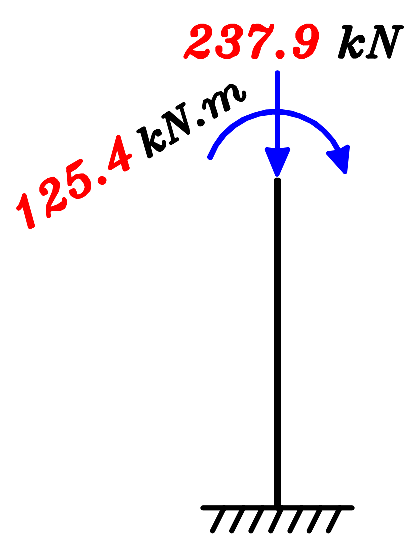




N.F.D.



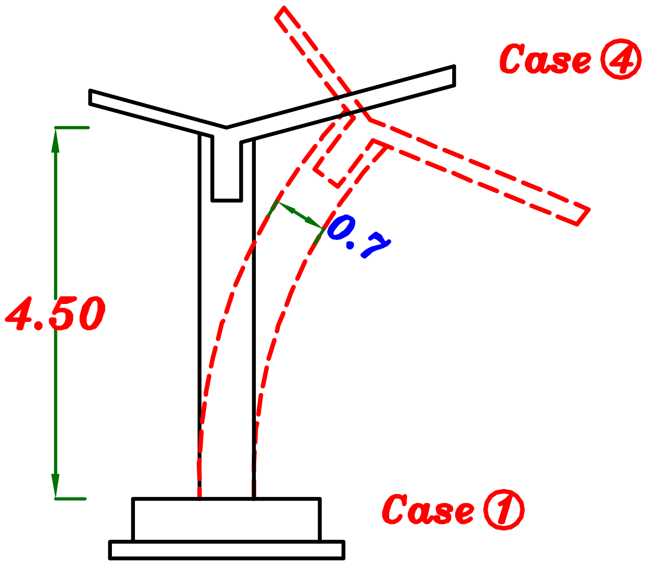
B.M.D.



Take the Column (400*700)

Check Buckling.

① In plane.

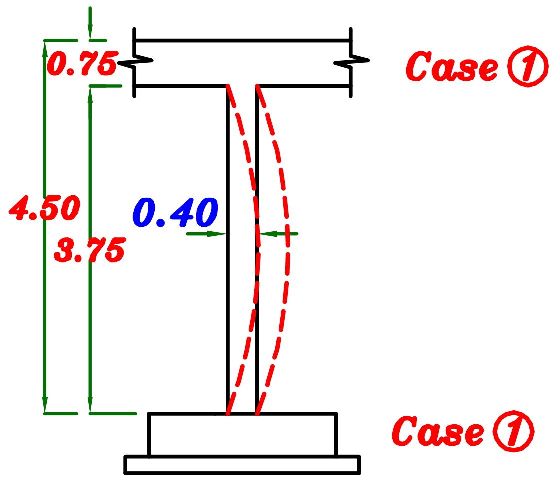


Upper Condition Case ④
Lower Condition Case ① } $k = 2.2$

$H_o = 4.50$ m

$$\lambda_{b_{in}} = \frac{2.2 * 4.5}{0.7} = 14.14 > 10$$

② Out of plane.



Upper Condition Case ①
Lower Condition Case ① } $k = 1.2$

$H_o = 3.75$ m

$$\lambda_{b_{out}} = \frac{1.2 * 3.75}{0.40} = 11.2 > 10$$

Take the bigger value of $\lambda_b = 14.1$ (In plane)

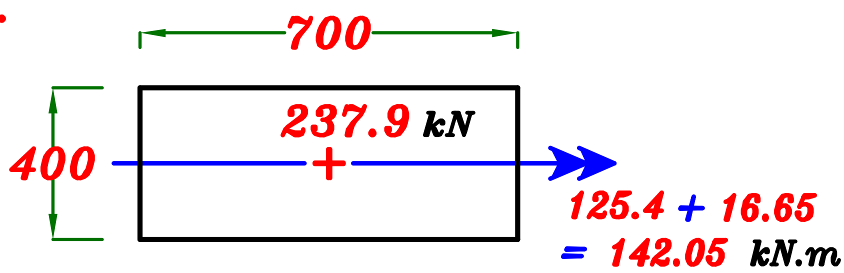
$$\delta = \frac{(\lambda_b)^2 * t}{2000} = \frac{14.14^2 * 0.7}{2000} = 0.07 \text{ m}$$

$$M_{add.} = P * \delta = 237.9 * 0.07 = 16.65 \text{ kN.m}$$

$$\because M_{des.} = M_{ext.} + M_{add.}$$

$$\therefore M_{des.} = 125.4 + 16.65$$

$$= 142.05 \text{ kN.m}$$



Design the Sec.

$$e = \frac{M}{P} = \frac{142.05}{237.9} = 0.597\ m \quad \therefore \frac{e}{t} = \frac{0.597}{0.7} = 0.85 > 0.5 \xrightarrow{use} e_s$$

$$e_s = e + \frac{t}{2} - c = 0.597 + \frac{0.70}{2} - 0.05 = 0.897\ m$$

$$M_s = P * e_s = 237.9 * 0.897 = 213.4\ kN.m$$

$$\therefore 650 = C_1 \sqrt{\frac{213.4 * 10^6}{25 * 400}} \longrightarrow C_1 = 4.45 \longrightarrow J = 0.817$$

$$\therefore A_s = \frac{M_s}{J F_y d} - \frac{P_{U.L.}}{(F_y \backslash \gamma_s)}$$

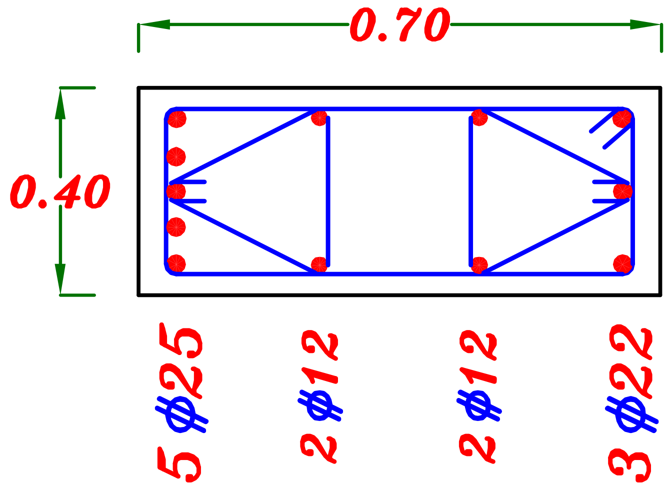
$$= \frac{213.4 * 10^6}{0.817 * 360 * 650} - \frac{237.9 * 10^3}{(360 \backslash 1.15)} = 356.27\ mm^2$$

$$A_{s_{min}} = \frac{0.25 + 0.052\ \lambda_{max}}{100} * b * t$$

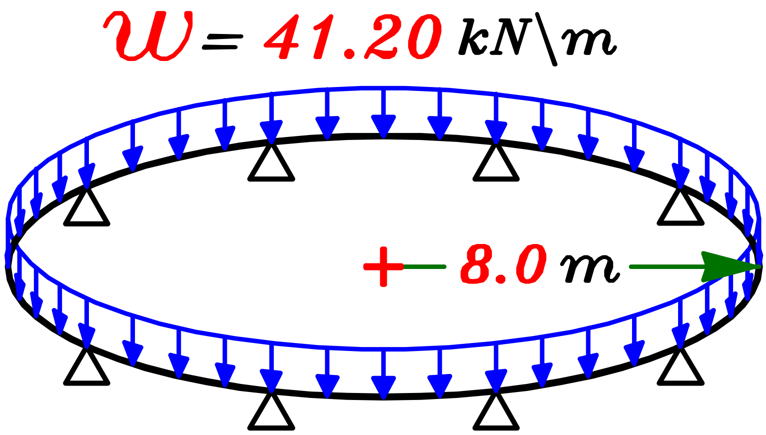
$$= \frac{0.25 + 0.052\ (14.14)}{100} * 400 * 700 = 2758.8\ mm^2 > A_s$$

$$\therefore \text{Take } A_s = A_{s_{min}} = 2239.3\ mm^2 \qquad 5 \phi 25$$

$$\text{Stirrup Hangers} = 0.4\ A_s = 0.4 * 2239.3 = 895.7\ mm^2 \qquad 3 \phi 22$$



Example.



$F_{cu} = 25\ N/mm^2$

$F_y = 360\ N/mm^2$

Beam (300 * 750)

No. of supports = 8.0

$W_{working} = 41.20$ kN\m

Radius of the beam = 8.0 m

Req.

1- Calculate the straining action on the beam.

2- Design the beam.

3- Draw details of RFT. in elevation and cross section of the beam.

From Tables

No. of supports	Load on each support	Max. Shearing Force	Max. Bending Moment at C.L. of Span	Max. Bending Moment Over C.L. of Column	Max. Torsional Moment	Centeral angle
n	R	$Q_{max.}$	M_{+Ve}	M_{-Ve}	$M_{t\,max.}$	θ
4	P/4	P/8	0.0176 Pr	– 0.0322 Pr	0.0053 Pr	19° 21`
6	P/6	P/12	0.0075 Pr	– 0.0148 Pr	0.0015 Pr	12° 44`
8	**P/8**	**P/16**	**0.0042 Pr**	**– 0.0083 Pr**	**0.0006 Pr**	**9° 33`**
10	P/10	P/20	0.0032 Pr	– 0.0052 Pr	0.0004 Pr	7° 36`
12	P/12	P/24	0.0019 Pr	– 0.0037 Pr	0.0002 Pr	6° 21`

$n = 8.0$

$P = w * 2\pi r = 41.20 * 2\pi * 8.0 = 2070.93 \text{ kN}$

max. $M_{+Ve} = 0.0042\, Pr = 0.0042 * 2070.93 * 8.0 = 69.58 \text{ kN.m}$

max. $M_{-Ve} = 0.0083\, Pr = 0.0083 * 2070.93 * 8.0 = 137.51 \text{ kN.m}$

max. $M_t = 0.0006\, Pr = 0.0006 * 2070.93 * 8.0 = 9.94 \text{ kN.m}$

$$Q_{max.} = \frac{P}{16} = \frac{2070.93}{16} = 129.43 \text{ kN}$$

Centeral angle $\theta = 9^\circ 33' = 9.55^\circ$

$$X = r * \theta * \frac{\pi}{180} = 8.0 * 9.55 * \frac{\pi}{180} = 1.33 \text{ m}$$

$Q_{cor.} = Q_{max} - w * X = 129.43 - 41.20 * 1.33 = 74.63 \text{ kN}$

Design beam B1

$b = 300 \text{ mm}$, $t = 750 \text{ mm}$

Sec. of max −Ve.

$M = 137.51 * 1.5 = 206.26 \text{ kN.m.}$

$$\therefore d = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\, b}} \quad \therefore 700 = C_1 \sqrt{\frac{206.26 * 10^6}{25 * 300}} \rightarrow C_1 = 4.22 \rightarrow J = 0.810$$

$$\therefore A_s = \frac{M_{U.L.}}{J\, F_y\, d} = \frac{206.26 * 10^6}{0.810 * 360 * 700} = 1010.5 \text{ mm}^2$$

Check $A_{s_{min.}}$

$A_{s_{req.}} = 1010.5 \text{ mm}^2$

$$\mu_{min.}\, b\, d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 700 = 656.25 \text{ mm}^2$$

$\therefore A_{s_{req.}} > \mu_{min.}\, b\, d \quad \therefore$ Take $A_s = A_{s_{req.}} = 1010.5 \text{ mm}^2$

Sec. of max +Ve.

$$M = 69.58 * 1.5 = 104.37 \text{ kN.m.}$$

$$\therefore \; d = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\, b}} \quad \therefore \; 700 = C_1 \sqrt{\frac{104.37 * 10^6}{25 * 300}} \rightarrow C_1 = 5.93 \rightarrow J = 0.826$$

$$\therefore \; A_S = \frac{M_{U.L.}}{J \, F_y \, d} = \frac{104.37 * 10^6}{0.826 * 360 * 700} = 501.4 \text{ mm}^2$$

Check $A_{s_{min.}}$

$$A_{s_{req.}} = 501.4 \text{ mm}^2$$

$$\mu_{min.}\, b\, d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 700 = 656.25 \text{ mm}^2$$

$$\therefore \; \mu_{min.}\, b\, d > A_{s_{req.}} \xrightarrow{\text{Use}} A_{s_{min.}}$$

$$\left.\begin{aligned} A_{s_{min.}} &= \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 700 = 656.25 \text{ mm}^2 \\ 1.3\, A_{s_{req.}} &= 1.3 * 501.4 = 651.8 \text{ mm}^2 \end{aligned}\right\} = 651.8 \text{ mm}^2$$

الأقل

Design due to Shear & Torsion.

$$q_u = \frac{Q}{b\, d} = \frac{1.5 * 74.63 * 10^3}{300 * 700} = 0.533 \text{ N/mm}^2$$

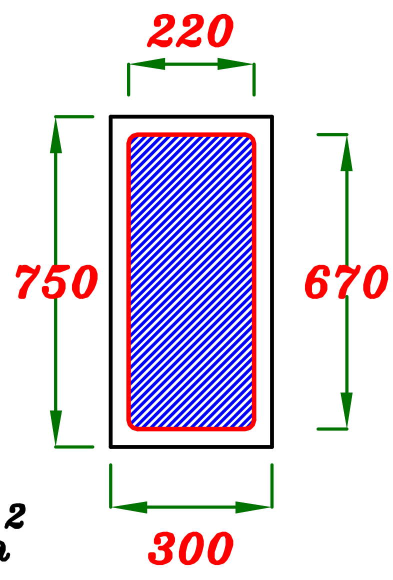
$$A_{oh} = 220 * 670 = 147400 \text{ mm}^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 147400 = 125290 \text{ mm}^2$$

$$P_h = 2 * 220 + 2 * 670 = 1780 \text{ mm}$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{147400}{1780} = 82.81 \text{ mm}$$

$$q_{tu} = \frac{M_{tu}}{2\, A_o\, t_e} = \frac{1.5 * 9.94 * 10^6}{2 * 125290 * 82.81} = 0.72 \text{ N/mm}^2$$



$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98 \ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245 \ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85 \ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.533^2 + 0.72^2} = 0.896 \ N/mm^2 < q_{u\,max} \quad \therefore \text{o.k.}$$

$\boxed{q_u < q_{cu} \ , \ q_{tu} > q_{t\,min}}$ $\therefore$ Use RFT. For Torsion only.

---

* Stirrups.

$$\therefore A_{str} = \frac{M_{tu} \ S_t}{(1.7) \ A_{oh} \ \left(\frac{F_y}{\delta_s}\right)} \qquad \therefore A_{str} = \frac{(1.5 * 9.94 * 10^6) * S_t}{(1.7)(147400)(240/1.15)}$$

$$\therefore \boxed{S_t = 3.507 * A_{str}}$$

* Take $\phi\ 8 \longrightarrow A_{str} = 50.3 \ mm^2$

$$\therefore S_t = 3.507 * A_{str} = 3.507 * 50.3 = 176.4 \ mm > 100 \ mm \quad \therefore \text{o.k.}$$

$$\therefore \text{No. of stirrups} \backslash m' = \frac{1000}{S} = \frac{1000}{176.4} = 5.66 = 6.0$$

$\therefore$ Use Closed Stirrups $\boxed{6\phi 8 \backslash m'}$ 2 branches.

* **Longitudinal Bars.**

$$S_t = \frac{1000}{6} = 166.66 \ mm$$

$$A_{sl} = \frac{A_{str} * P_h}{S_t}\left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right) = \frac{(50.3 * 1780)}{166.66}\left(\frac{240}{360}\right) = 358.15 \ mm^2$$

$$\therefore \frac{A_{sl}}{4} = \frac{358.15}{4} = 89.53 \ mm^2$$

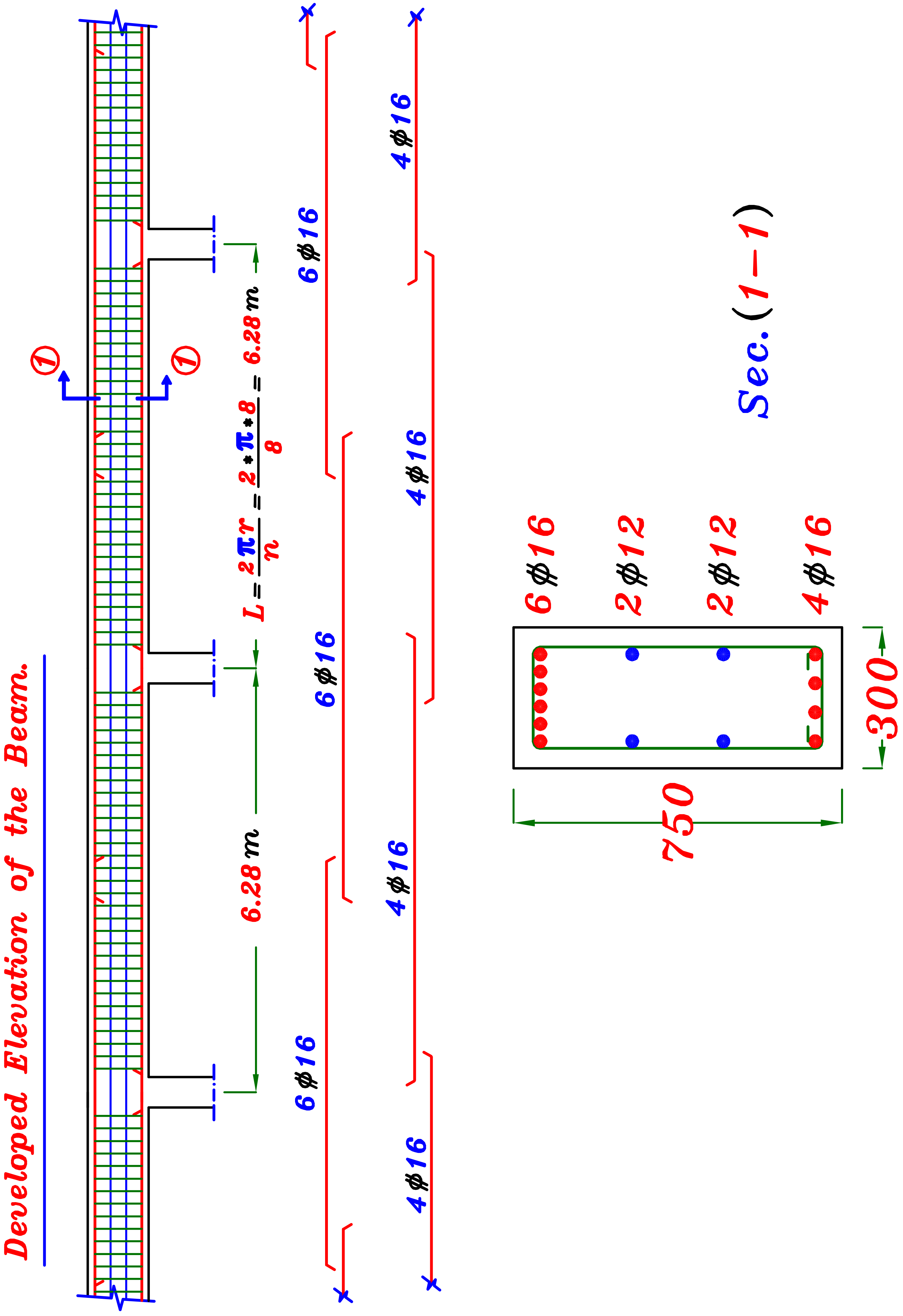
$$A_{s\,-Ve} = A_s + \frac{A_{sl}}{4} = 1010.5 + 89.53 = 1100.03 \ mm^2$$

$$6 \phi 16$$

$$\therefore n = \frac{b - 25}{\phi + 25} = \frac{300 - 25}{16 + 25} = 6.70 = 6.0$$

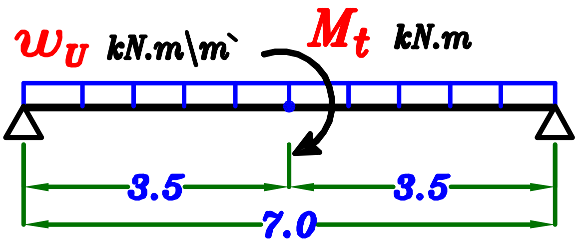
$$A_{s\,+Ve} = A_s + \frac{A_{sl}}{4} = 651.8 + 89.53 = 741.33 \ mm^2$$

$$4 \phi 16$$

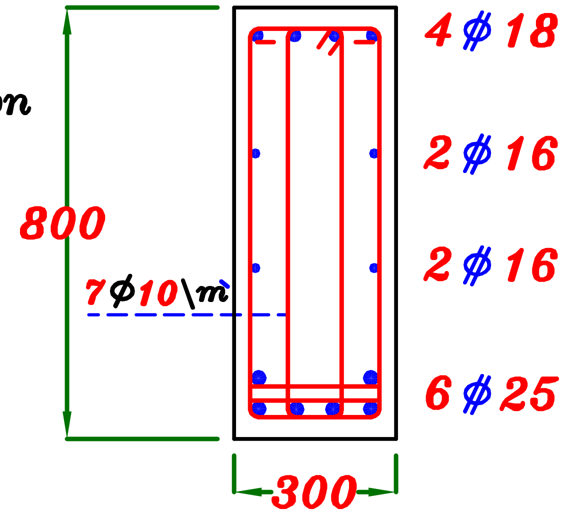


Developed Elevation of the Beam.
1
1
L = 2πr / n = 2*π*8 / 8 = 6.28 m
6.28 m
6φ16
6φ16
6φ16
4φ16
4φ16
4φ16
4φ16
Sec. (1–1)
6φ16
2φ12
2φ12
4φ16
750
300

Example.



The Following Fig. shows a simple girder subjected to uniform distributed Factored load (w_U) including own weight and local torque moment (M_t) at mid span. It is required to calculate the max. torque moment (M_t), For the girder and its section given in the Figure.

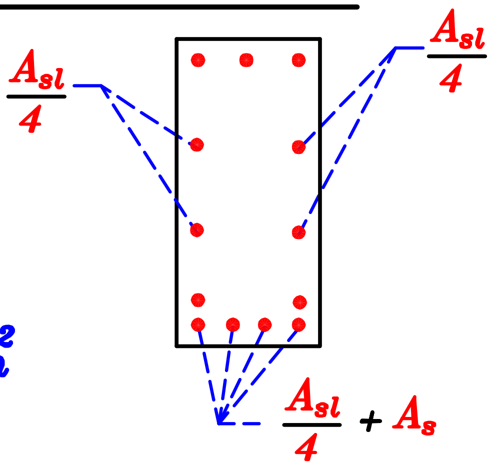


Data.

$F_{cu} = 30$ N\mm^2

$F_y = 400$ N\mm^2

Solution.

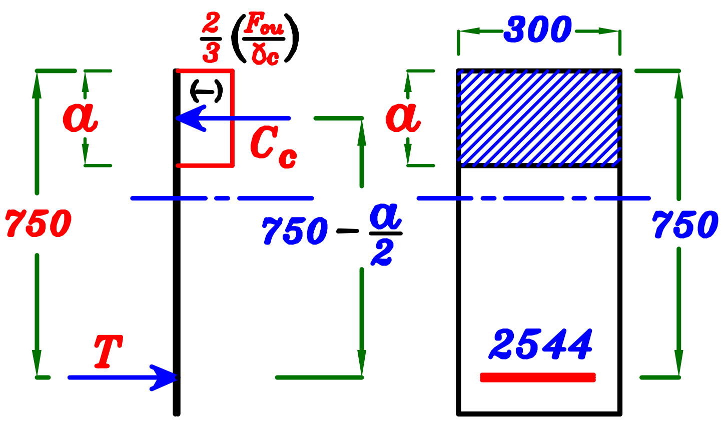


$\frac{A_{sl}}{4} = 2 \phi 16$

A_s(From momemt) $= 6\phi 25 - 2\phi 16$

$= 2946 - 402 = 2544\ mm^2$

Use First Principles to get $M_{U.L.}$



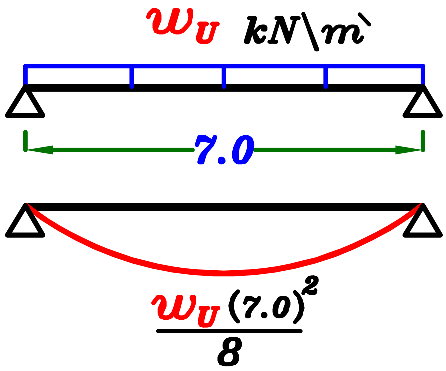
$$\frac{2}{3}\,\frac{F_{cu}}{\gamma_c} * a * b = A_s * \frac{F_y}{\gamma_s}$$

$$\frac{2}{3}\left(\frac{30}{1.5}\right)(a)(300) = (2544)\left(\frac{400}{1.15}\right)$$

$$a = 221.2\,mm > 0.1\,d$$

$$M_{U.L.} = \frac{2}{3}\,\frac{F_{cu}}{\gamma_c}\, a\, b\left(d - \frac{a}{2}\right) = \frac{2}{3}\left(\frac{30}{1.5}\right)(221.2)(300)\left(750 - \frac{221.2}{2}\right)$$

$$= 565741120\ N.mm = 565.7\ kN.m$$

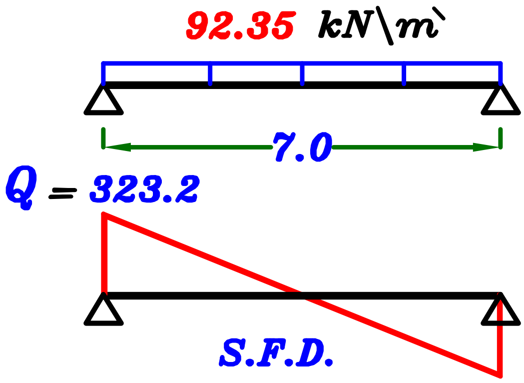


$$\because \; M_{U.L.} = 565.7 = \frac{w_U (7.0)^2}{8}$$

$$\therefore \; \boxed{w_U = 92.35 \;\; kN\backslash m`}$$

$$Q_{max} = \frac{w * L}{2} = 323.2 \; kN$$

$$q_u = \frac{Q}{b\,d} = \frac{323.2 * 10^3}{300 * 750} = 1.436 \;\; N\backslash mm^2$$



$$\therefore \; q_{cu} = (0.24)\sqrt{\frac{30}{1.5}} = 1.07 \; N\backslash mm^2$$

$$S_s = S_t = \frac{1000}{7.0} = 142.85 \;\; mm$$

$$q_u - \frac{q_{cu}}{2} = \frac{n\, A_s (F_y\backslash \delta_s)}{b \;\; S_s} \qquad \therefore \;\; 1.436 - \frac{1.07}{2} = \frac{4 * A_s\,(240/1.15)}{(300)\,(142.85)}$$

$$\therefore \; \boxed{A_s = 46.25 \; mm^2}$$

$$\because \; A_{s_{outer}} = A_{str} + A_s = A_{str} + 46.25 = 78.5 \; mm^2 \qquad \boxed{A_{str} = 32.25 \; mm^2}$$

$$x_1 = 220 \; mm \, , \;\; y_1 = 720 \; mm \; , \;\; A_{oh} = 220 * 720 = 158400 \; mm^2$$

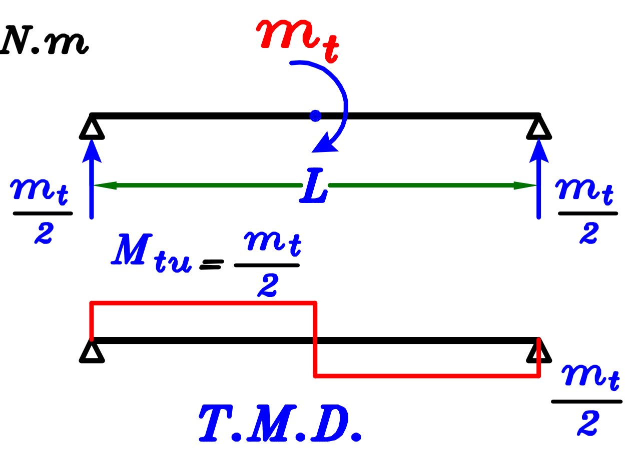
$$\because \; A_{str} = \frac{M_{tu} \;\; S_t}{(1.7) \;\; A_{oh} \;\; \left(\frac{F_y}{\delta_s}\right)} \qquad \therefore \; 32.25 = \frac{M_{tu} \; * \; (142.85)}{(1.7)(158400)\,(240/1.15)}$$

$$\therefore \; M_{tu} = 12687234.7 \;\; N.mm \; = \; 12.68 \;\; kN.m$$

$$\because \;\; M_{tu} = \frac{m_t}{2}$$

$$\therefore \;\; m_t = 12.68 * 2 = 25.36 \;\; kN.m$$

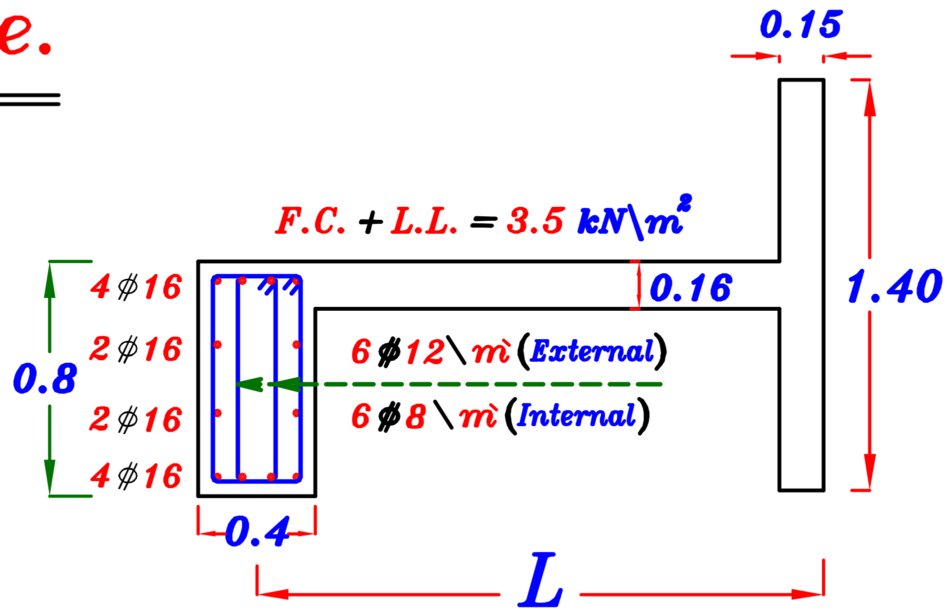
$$\therefore \; \boxed{M_t = 25.36 \;\; kN.m}$$



Example.

$F_{cu} = 25 \ N\backslash mm^2$

$F_y = 360 \ N\backslash mm^2$



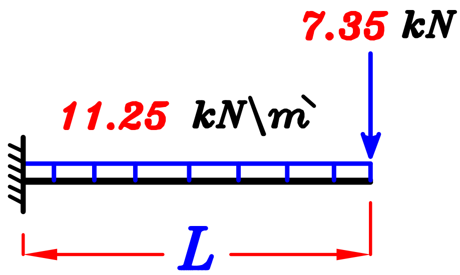
The Figure shows the cross-section dimensions and RFT. of continuous beam supported on columns spaced 6.0 m. The beam has a cantilever solid slab of 0.16 m thickness. It is required to calculate the safe length of the cantilever slab to satisfy the RFT. & loads shown in Fig.

$w_s = 1.5\,(0.16 * 25 \ + 3.50) = 11.25 \ kN\backslash m^2$

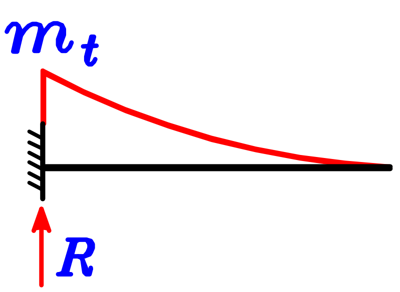
parapet weight $= 1.4\,(0.15 * 1.4 * 1.0) * 25 = 7.35 \ kN\backslash m`$

o.w. (beam) $= 1.4\,(0.4 * 0.8 * 1.0) * 25 = 11.2 \ kN\backslash m`$

Strip in the slab.

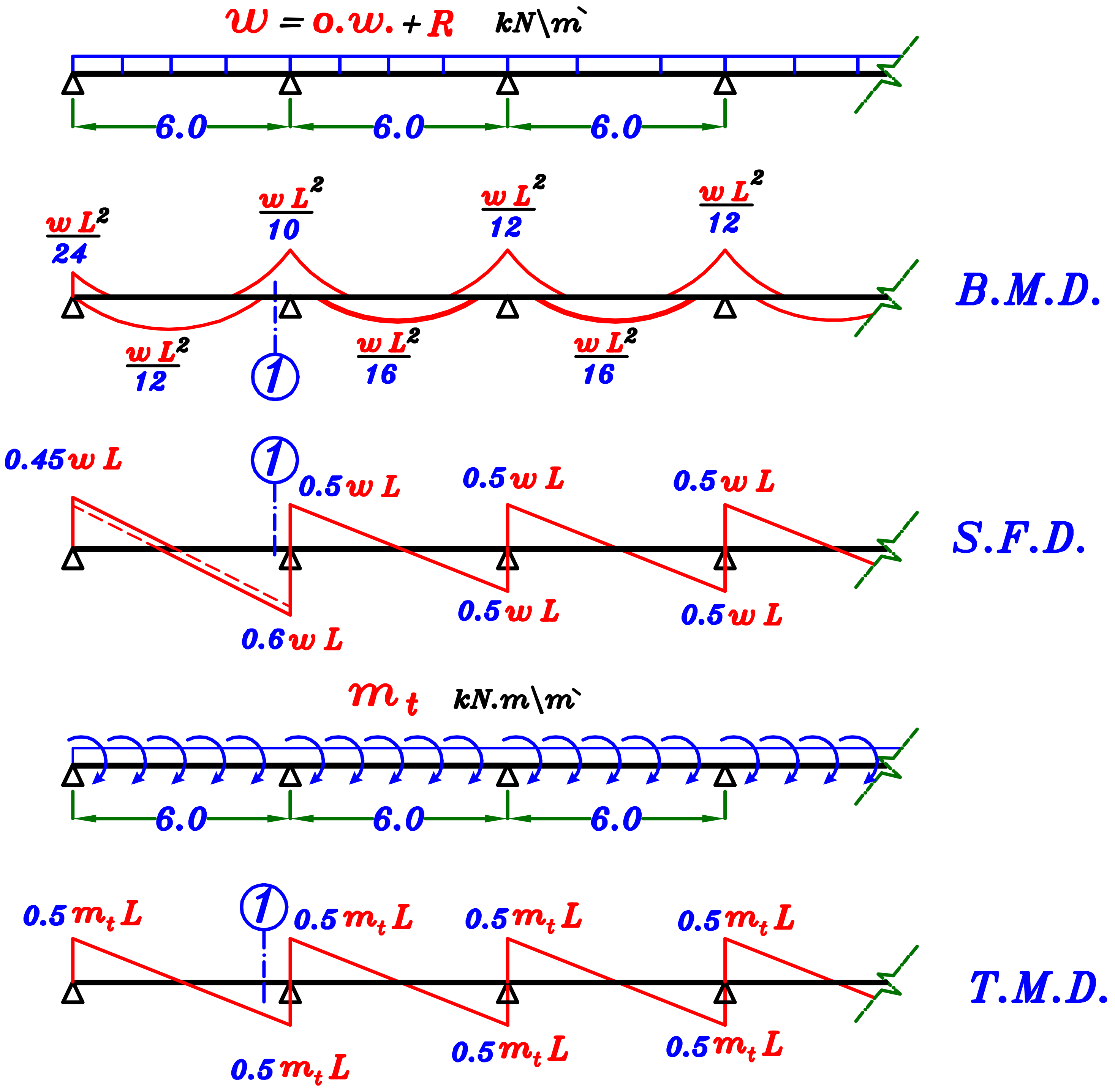


$$\boxed{R = 11.25\,L + 7.35} \quad kN$$



$$\boxed{\begin{aligned} m_t &= 7.35\,L + 11.25\,\frac{L^2}{2} \\ &= 7.35\,L + 5.625\,L^2 \end{aligned}} \quad kN.m$$

$$\boxed{\begin{aligned} w = o.w. + R &= 11.2 + (11.25\,L + 7.35) \\ &= 18.55 + 11.25\,L \end{aligned}} \quad kN\backslash m$$



For Sec. 1

$$M_{U.L.} = \frac{w L^2}{10} = \frac{(18.55 + 11.25\, L) * 6.0^2}{10} \quad \therefore \boxed{M_{U.L.} = 66.78 + 40.5\, L} \ \text{kN.m}$$

$$Q = 0.6\, w\, L = 0.6\, (18.55 + 11.25\, L) * 6.0 \quad \therefore \boxed{Q_{U.L.} = 66.78 + 40.5\, L} \ \text{kN}$$

$$M_t = 0.5\, m_t\, L = 0.5\, (7.35\, L + 5.625\, L^2) * 6.0$$

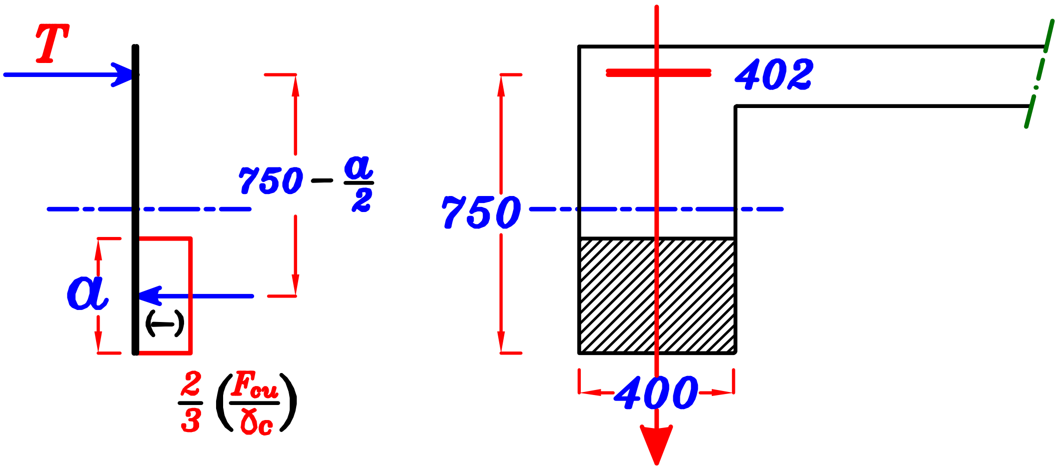
$$\therefore \boxed{M_t = 22.05\, L + 16.87\, L^2} \ \text{kN.m}$$

For Bending Moment.

$$\frac{A_{sl}}{4} = 2\phi 16$$

A_s (From moment) $= 4\phi 16 - 2\phi 16 = 804 - 402 = 402\ mm^2$

Neglect A_s'



Use First Principles to get $M_{U.L.}$

$$\frac{2}{3}\frac{F_{cu}}{\gamma_c} * a * b = A_s * \frac{F_y}{\gamma_s}$$

$$\frac{2}{3}\left(\frac{25}{1.5}\right)(a)(400) = (402)\left(\frac{360}{1.15}\right) \longrightarrow a = 28.3\ mm < 0.1\,d$$

$$M_{U.L.} = 0.826\, A_s\, F_y\, d = 0.826\,(402)(360)(750)$$

$$= 89654040\ N.mm = 89.65\ kN.m$$

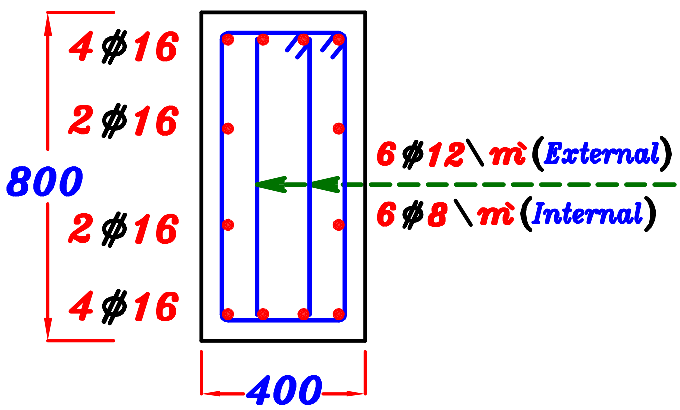
$$\therefore \boxed{M_{U.L.} = 89.65\ kN.m}$$

$n = 4.0$

$A_{s\,inner} = \phi 8 = A_s = 50.3\ mm^2$

$A_{s\,outer} = \phi 12 = A_{str} + A_s = 113\ mm^2$

$\therefore A_{str} = 113 - 50.3 = 62.7\ mm^2$



For Shear

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98 \ N\backslash mm^2 \quad , \quad S_s = S_t = \frac{1000}{6.0} = 166.67 \ mm$$

$$\because \ q_u - \frac{q_{cu}}{2} = \frac{n \ A_s (F_y \backslash \gamma_s)}{b \ S_s}$$

$$\therefore \ q_u - \frac{0.98}{2} = \frac{4 \ (50.3) \ (360 \backslash 1.15)}{(400)\ (166.67)} \longrightarrow q_u = 1.434 \ N\backslash mm^2$$

$$\because \ q_u = \frac{Q}{b \ d} \qquad \therefore \ 1.434 = \frac{Q}{(400)\ (750)} \longrightarrow Q = 430200 \ N$$

$$\therefore \ \boxed{Q_{U.L.} = 430.2 \ kN}$$

For Torsional Moment.

$$A_{s\ inner} = \phi 8 = A_s = 50.3 \ mm^2$$

$$A_{s\ outer} = \phi 12 = A_{str} + A_s = 113 \ mm^2$$

$$\therefore \ A_{str} = 113 - 50.3 = 62.7 \ mm^2$$

$$x_1 = 320 \ mm \quad , \quad y_1 = 720 \ mm$$

$$A_{oh} = 320 * 720 = 230400 \ mm^2$$

$$S_s = S_t = \frac{1000}{6.0} = 166.67 \ mm$$

$$\because \; A_{str} = \frac{M_{tu} \; S_t}{(1.7) \; A_{oh} \; (F_y \backslash \gamma_s)}$$

$$\therefore \; 62.7 = \frac{M_{tu} * (166.67)}{(1.7)(230400)(360/1.15)} \longrightarrow M_{tu} = 46126039 \text{ N.mm}$$

$$\therefore \; \boxed{M_t = 46.12 \text{ kN.m}}$$

To get the safe length of the cantilever get the least of L_1, L_2, L_2

- $M_{U.L.} = 89.65$ kN.m $= 66.78 + 40.5\, L_1 \longrightarrow L_1 = 0.564$ m
- $Q_{U.L.} = 430.2$ kN $= 66.78 + 40.5\, L_2 \longrightarrow L_2 = 8.97$ m
- $M_t = 46.12$ kN.m $= 22.05\, L_3 + 16.87\, L_3^2 \longrightarrow L_3 = 1.12$ m

$$\therefore \; \boxed{L = 0.564 \text{ m}}$$

Example.

For The given Figure of structural plan.

It is required to :

Draw B.M.D. , S.F.D. & T.M.D. For the main Girder (G)

Data.

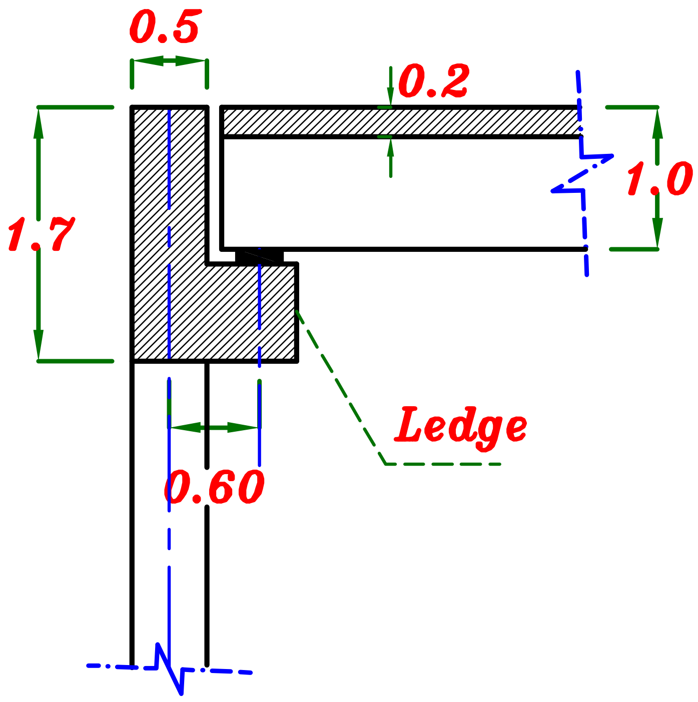
$F_{cu} = 40 \ N\backslash mm^2$

$F_y = 400 \ N\backslash mm^2$

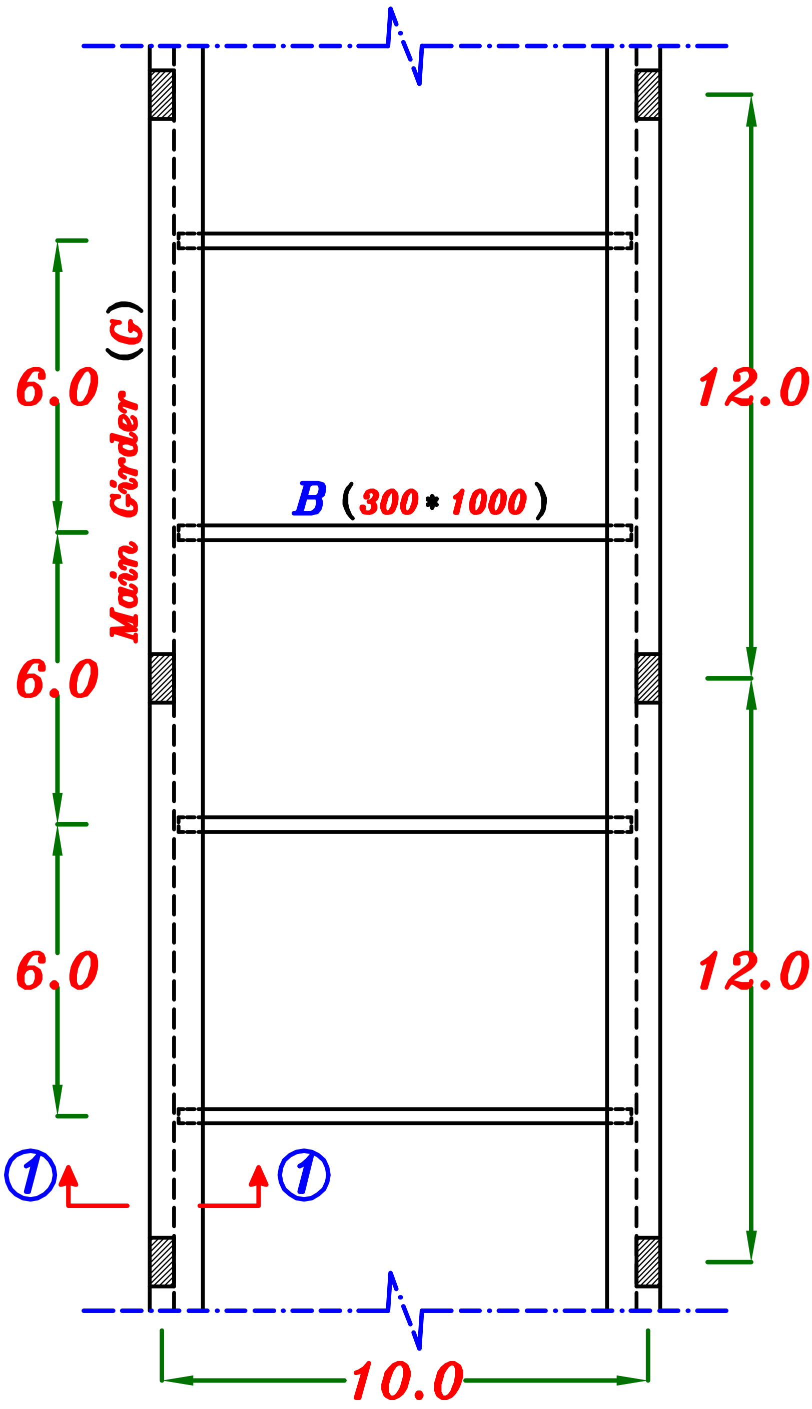
$F.C. = 3.0 \ kN/m^2$

$L.L. = 5.0 \ kN/m^2$

$t_s = 200 \ mm$



Sec. (1–1)



Plan

Neglect effect of Ledge إهمل تأثير النتوء

Design of Ledge is not required

Solution.

$$w_s = 1.4\,(t_s\,\gamma_c + F.C.) + 1.6\,(L.L.)$$

$$w_s = 1.4\,(0.20 * 25 + 3.0) + 1.6\,(5.0) = 19.2\ kN\backslash m^2$$

$$o.w._{(Beam)} = 1.4\,(b * t * \gamma_c) = 1.4\,(0.3 * 1.0 * 25) = 10.5\ kN\backslash m'$$

$$o.w._{(Girder)} = 1.4\,(b * t * \gamma_c) = 1.4\,(0.5 * 1.7 * 25) = 29.75\ kN\backslash m'$$

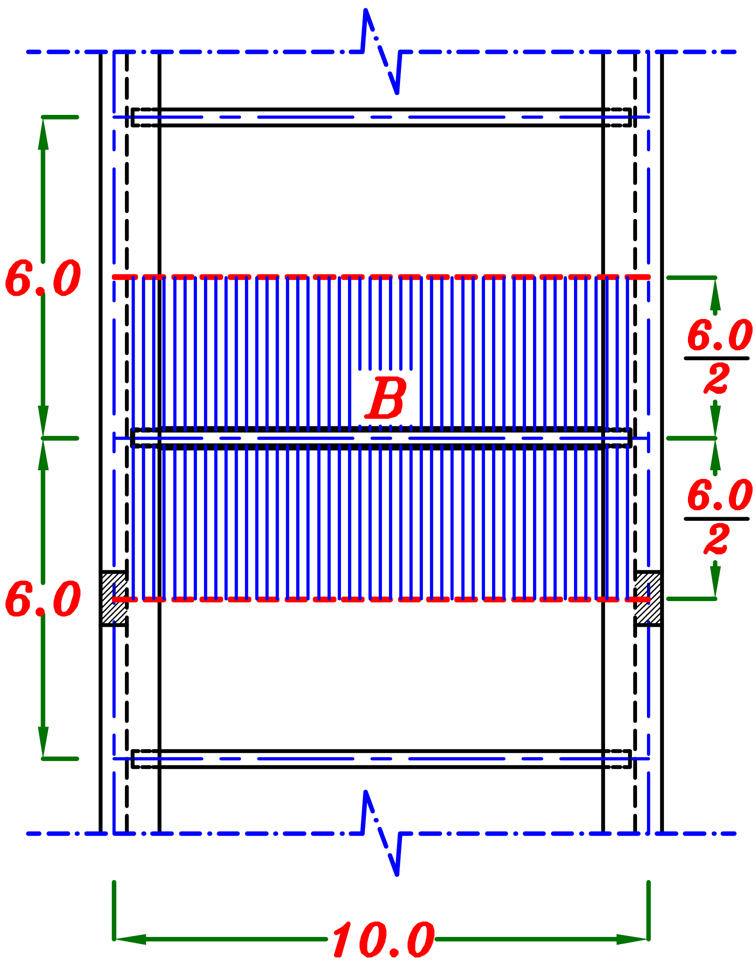
Neglect effect of Ledge إهمل تأثير النتؤ

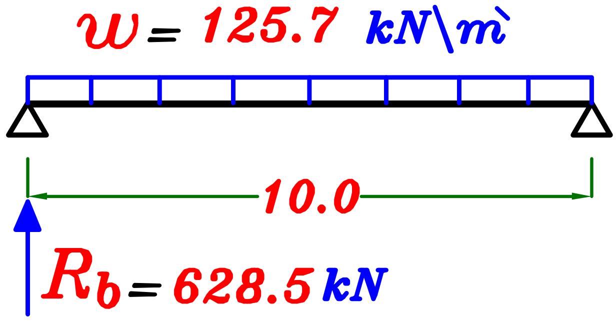
Beam.

$$w_{(Beam)} = o.w. + 2\,w_s\,\frac{L_s}{2}$$

$$= 10.5 + 2\,(19.2)\,\frac{6.0}{2}$$

$$= 125.7\ kN\backslash m'$$



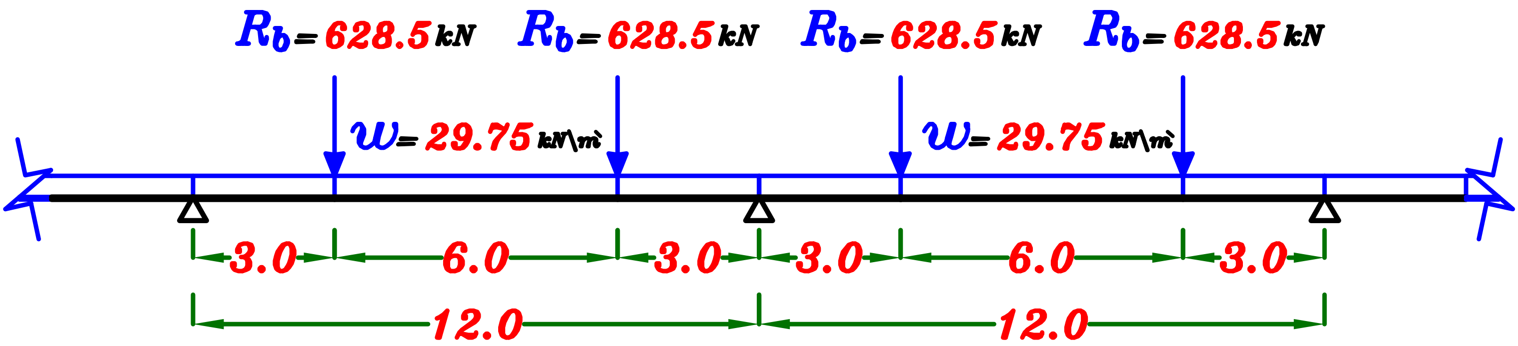


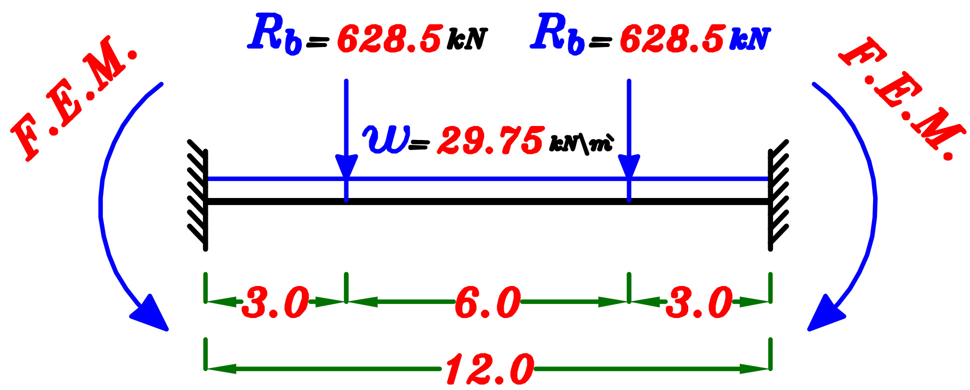
$$\boxed{R_b = 628.5\ kN}$$

Main Girder.

$W\,(\text{Girder}) = O.W. = 29.75 \ kN\backslash m'$

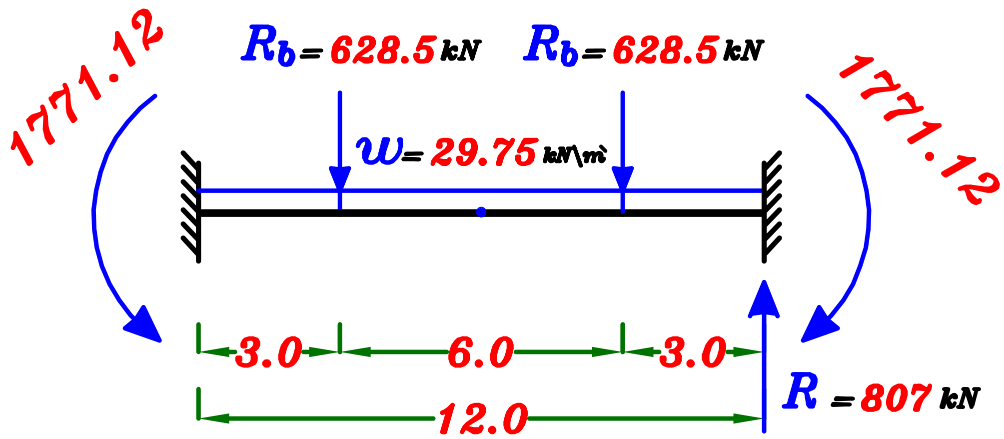
Loads on Girder.





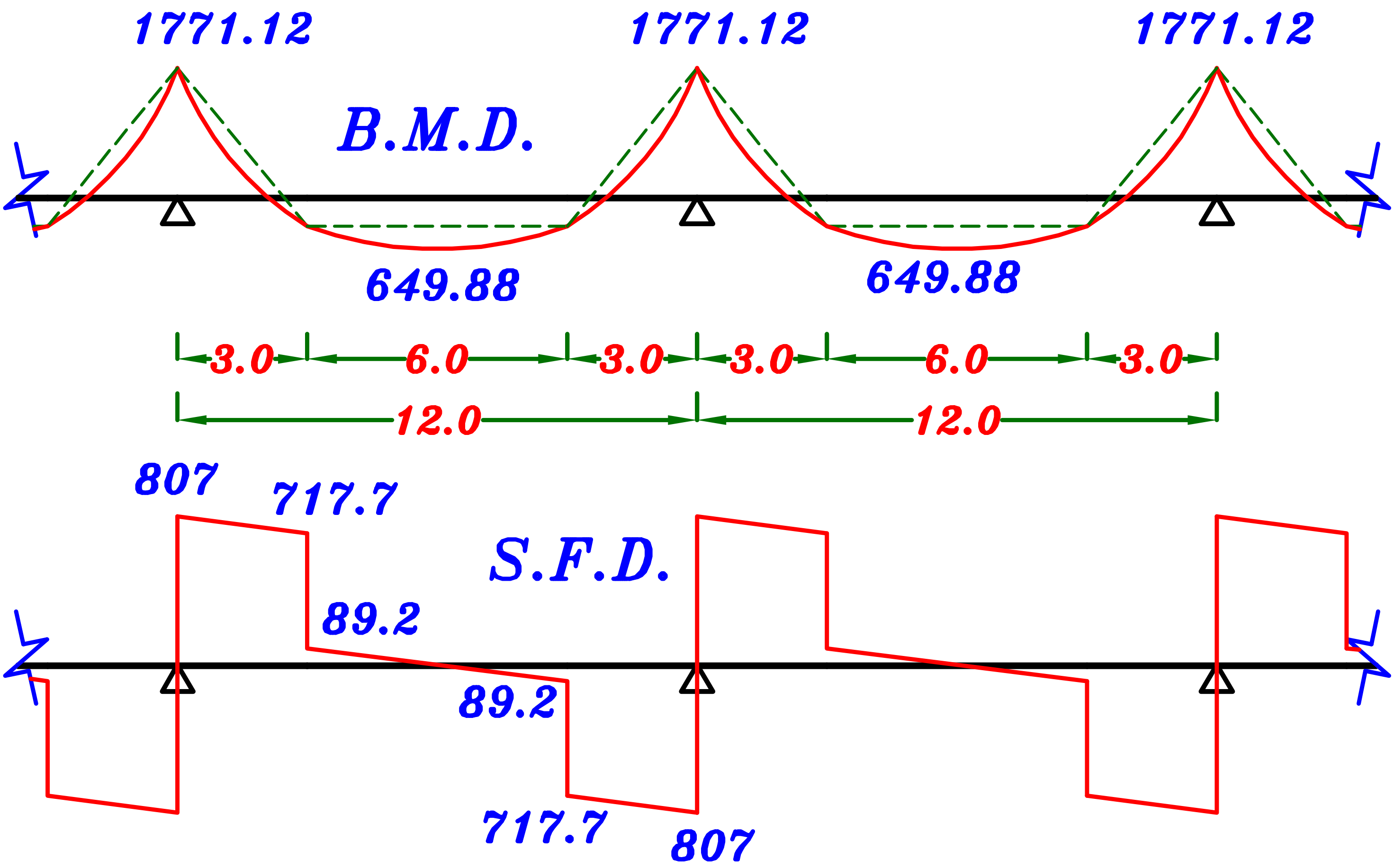
$$\text{Fixed End Moment} = \frac{w L^2}{12} + \frac{P\,a\,(b)^2}{L^2} + \frac{P\,b\,(a)^2}{L^2}$$

$$= \frac{29.75 * 12^2}{12} + \frac{628.5 * 3 * 9^2}{12^2} + \frac{628.5 * 9 * 3^2}{12^2} = 1771.12 \ kN.m$$

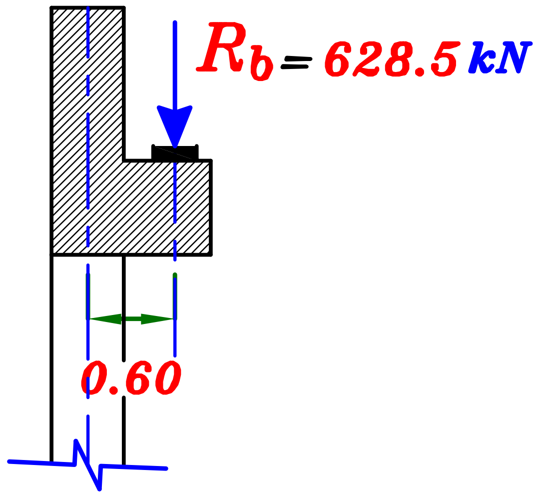


$$B.M.\,(\text{at mid. span}) = 807\,(6.0) - 1771.12 - 29.75 * 6.0\,(3.0) - 628.5\ (3.0)$$

$$= 649.88 \ kN.m$$



Torsion on Girder.



$$M_t = 628.5 * 0.60 = 377.1 \text{ kN.m}$$